

NASA Goddard Space Flight Center
Laboratory for Extraterrestrial Physics
Greenbelt, Maryland 20771

1 INTRODUCTION

The NASA Goddard Space Flight Center (GSFC) Laboratory for Extraterrestrial Physics (LEP) conducts a broad program of experimental and theoretical scientific research on the heliosphere, the interstellar medium, the magnetospheres, ionospheres and upper atmospheres of the planets, including Earth.

LEP space scientists study the structure and dynamics of the magnetospheres of the planets including Earth. Their research programs encompass the magnetic fields intrinsic to many planetary bodies as well as their charged particle environments and plasma-wave emissions. The LEP also conducts research into the nature of planetary ionospheres and their coupling to both the upper atmospheres and their magnetospheres. Finally, the LEP carries out a broad-based research program in heliospheric physics covering the origins of the solar wind, its evolution and outward propagation through the solar system all the way to its termination where it encounters the local interstellar medium. Special emphasis is placed on the study of solar Coronal Mass Ejections (CME's), shock waves, the evolution of magnetohydrodynamic turbulence, and the structure and properties of the fast and slow solar wind.

LEP planetary scientists investigate the chemistry and physics of planetary stratospheres and tropospheres and of solar system bodies including meteorites, asteroids, comets, and planets. The LEP conducts a focused program in astronomy, particularly in the infrared and in short as well as very long radio wavelengths. We also perform an extensive program of laboratory research, including spectroscopy and physical chemistry related to astronomical objects.

The LEP proposes, develops, fabricates, and integrates experiments on Earth-orbiting, planetary, and heliospheric spacecraft to measure the characteristics of planetary atmospheres and magnetic fields, and electromagnetic fields and plasmas in space. We design and develop spectrometric instrumentation for continuum and spectral line observations in the x-ray, gamma-ray, infrared, and radio regimes; these are flown on spacecraft to study the interplanetary medium, asteroids, comets, and planets. Sub-orbital sounding rockets and ground-based observing platforms form an integral part of these research activities.

A fairly large number of post-doctoral and graduate students work in the LEP on research projects. The LEP is committed to NASA's Education and Public Outreach effort. A vigorous summer internship program provides both high school and college students an opportunity to enrich their educational experience through hands-on

scientific research.

LEP is organized into five Branches: (1) Astrochemistry, (2) Planetary Systems, (3) Interplanetary Physics, (4) Planetary Magnetospheres, and (5) Electrodynamics. These branches work together to carry out NASA's strategic plan as embodied in the Origins, Structure and Evolution of the Universe, and Sun-Earth Connection themes.

This report covers the period from approximately October 2002 through September 2003.

2 PERSONNEL

Dr. Richard Vondrak continues as Chief of the LEP. Mr. Franklin Ottens is Assistant Chief. The Branch Heads are: Dr. Joseph Nuth (Astrochemistry); Dr. Thomas Moore (Interplanetary Physics); Dr. L. Drake Deming (Planetary Systems); Dr. Steven Curtis (Planetary Magnetospheres), and Dr. James Slavin (Electrodynamics). The Laboratory Senior Scientists are Drs. Richard Goldberg, Michael Mumma, Keith Ogilvie, and Louis Stief. The civil service scientific staff consists of Dr. Mario Acuña, Dr. John Allen, Dr. Robert Benson, Dr. Gordon Bjoraker, Dr. John Brasunas, Dr. David Buhl, Dr. Leonard Burlaga, Dr. Cynthia Cheung, Dr. Gordon Chin, Dr. Regina Cody, Dr. Michael Collier, Dr. John Connerney, Dr. Michael Desch, Dr. Jason Dworkin, Mr. Fred Espenak, Dr. Joseph Fainberg, Dr. Donald Fairfield, Dr. William Farrell, Dr. Michael Flasar, Dr. Mei-Ching Fok, Dr. Barbara Giles, Dr. David Glenar, Dr. Melvyn Goldstein, Dr. Natchimuthuk Gopalswamy, Dr. Adolfo F.-Viñas, Dr. Joseph Grebowsky, Dr. Michael Hesse, Dr. Donald Jennings, Mr. Michael Kaiser, Dr. John Keller, Dr. Alexander Klimas, Dr. Theodor Kostiuk, Dr. Brook Lakew, Dr. Guan Le, Dr. Ronald Lepping, Dr. Robert MacDowall, Dr. William Maguire, Dr. Michael DiSanti, Dr. Marla Moore, Dr. David Nava, Dr. Walter Payne, Dr. John Pearl, Dr. Robert Pfaff, Dr. Dennis Reuter, Dr. D. Aaron Roberts, Dr. Paul Romani, Dr. David Sibeck, Dr. Amy Simon-Miller, Dr. Edward Sittler, Dr. Michael Smith, Dr. Adam Szabo, Dr. Jacob Trombka, and Dr. Peter Wasilewski. The LEP also consists of Co-op Graduate students, Mr. Daniel Martinez, Ms. Kelly Fast, Mr. Walter Allen, Ms. Talana Jackson, and Ms. Lucy Lim. The Laboratory also has a large scientific staff who are not civil servants. The following are National Research Council Associates (NRC): Dr. Stephen Christon, Dr. John Dorelli, Dr. Roberto Fernandez-Borda, Dr. Jesper Gjerloev, Dr. Natasha M. Johnson, Dr. Kristi Keller, Dr. Hina Khan, Dr. Gunther Kletetschka, Dr. Alexander Kutepov, Dr. Jan Merka, Dr. André Pimentel, Dr. Kristine Sigsbee, Dr.

Christian Steigies, Dr. Erika Gibb, Dr. Eija Tanskanen, Dr. Guido Sonnabend, Dr. Vadim Uritsky, Dr. Arcadi Usmanov and Dr. Wayne Keith. The following scientists work at the LEP as either contractors to GSFC or as long-term visiting faculty: (L3EER) Dr. Daniel Berdichevsky, Dr. Henry Freudenreich, Dr. Roger Hess, and Dr. Vladimir Osherovich; (Raytheon/ITSS) Dr. Ashraf Ali, Dr. Rainer Fettig, Dr. Maria Kuznetsova, and Dr. Lutz Rastätter; (Universities Space Research Association (USRA)) Dr. Sheng-Hsien Cheng, Dr. Nikolai Tsyganenko, Dr. Dimitris Vassiliadis, Dr. Sean Chen, Dr. Yusuke Ebihara, Dr. Phillip Webb, Dr. Yihua Zheng, Dr. Jeremy Richardson, and Mr. Benjamin Pilkerton; (ITMI) Dr. Michael Rilee; (Computer Sciences Corporation (CSC)) Dr. Larry Evans; (Catholic University of America) Dr. Pamela Clark, Dr. Dana Crider, Dr. Tamara Dickinson, Dr. Frank Ferguson, Dr. Patrick Michael, Dr. David Steyert, Dr. Guillermo Stenborg, Mr. George McCabe, Dr. Robert Nelson, Dr. Fred Nesbitt, Dr. Michael Reiner, Dr. Neil DelloRusso, and Dr. Richard Starr; (Space Science Applications, Inc. (SSAI)) Dr. Richard Achterberg, and Dr. Ronald Carlson; (University of Maryland, College Park) Dr. Dennis Chornay, Dr. Thejappa Golla, Dr. Tilak Hewagama, Dr. John Hillman, and Mr. Virgil Kunde; (IONA College) Dr. Robert Novak; (Cornell University) Dr. Barney Conrath and Dr. Paul Schinder; (Challenger Center for Space Science Education) Dr. Jeffrey J. Goldstein and Dr. Timothy Livengood; (NOMAD Research) Dr. Dean Pesnell; (John's Hopkins Applied Physics Laboratory (APL/IPA)) Dr. Nicola Fox; (Eckerd College) Dr. Reginald Hudson; (University of Toledo) Mr. Boncho Bonev; (University of Alabama) Dr. Chin-Chun Wu; (University of Tennessee) Dr. William Blass.

A small and very capable staff of engineers, technicians, secretaries, and computational personnel also support the work of the LEP scientists.

2.1 Tribute to Recently Retired Scientists

Two exceptional LEP scientists retired in 2002 after many years of service to NASA: Dr. Robert Hoffman and Dr. Richard Fitzenreiter. Today, our work in LEP builds on the legacy left behind by these individuals and others who have previously retired. Some of them have Emeritus status and continue to contribute to the scientific programs of the LEP.

Richard (Dick) J. Fitzenreiter retired after a 40 year career at GSFC. His commitment to scientific and technical excellence is exemplified in his many research accomplishments on the subject of the Earth's magnetosphere, the bowshock and foreshock, and magnetospheric plasma resulting in the scientific success of numerous Center Programs such as Alouette, ISEE and WIND.

Robert (Bob) Hoffman retired after a distinguished 40 year career of exceptional service, where he upheld the highest standards for a NASA scientist. The charged particle investigations he developed for the Pioneer, Explorer, Atmospheric Explorer, and the Orbiting Geophysical Observatory missions were among the pathfind-

ers that gave us our first views of the Earth's high altitude plasma environment. The Explorer 45, Dynamics Explorer and Polar missions, for which Bob served with distinction as Project Scientist, provided the foundation for our present understanding of the origins of geomagnetic storms and the causes of the aurora. More recently, as the Living with a Star Project Scientist for Geospace, he forged mutually beneficial and enduring partnerships between the Goddard Space Flight Center, the Applied Physics Laboratory, and the space science community to produce a far reaching, yet detailed vision for NASA's first space weather research program. Finally, Bob's research into the dynamics of charged particles in the Earth's magnetosphere and the electrodynamics of the auroras has yielded numerous important results and helped to establish the LEP as a Center of Excellence for ionospheric and magnetospheric research.

3 ASTROCHEMISTRY

3.1 Laboratory Studies of Astrophysical Dust Analogs: Condensation, Catalysis and Growth

Condensation of solid particles from mixed vapors of Fe-Mg-Si metals in hydrogen gas mixed with oxygen to yield a flame, yield separate populations of amorphous iron silicate and magnesium silicate grains plus small quantities of MgO, SiO and FeO. These results are consistent with the hypothesis that vapor-phase nucleation and growth occurs at metastable eutectics in the ternary phase diagram. If this proves to be true for other condensing systems, then it will make prediction of the condensate composition from any astrophysical source much easier, while the compositions of oxide grains in the interstellar medium will be restricted to a small subset of the potential phase space.

We have demonstrated that amorphous iron silicate grains are remarkably good catalysts that can promote the disruption of both the CO and molecular nitrogen triple bonds. Grain surface reactions involving only hydrogen, CO and nitrogen have been shown to produce an amazing array of complex organic molecules including alkanes, poly-aromatic hydrocarbons, alcohols, amines, amides, imides and organic acids. In more recent experiments we have studied the hydration of the amorphous iron silicate catalyst after it has become coated with carbonaceous products of these grain-surface reactions. We find that after relatively low temperature exposure to liquid water, as might have happened on an asteroid early in the history of the solar system, we produce a material that appears to be closely related to meteoritic 'kerogen' extracted from primitive carbonaceous chondrites.

Studies of the efficiency of crystal growth from the vapor have been carried out in microgravity using NASA's KC-135 Reduced Gravity Research Aircraft. We find that only 3 atoms out of every 100,000 that strike a growing zinc crystal actually stick and become incorporated into the growing grains. We have applied these results to the formation of crystalline silicon carbide grains

in the atmospheres of asymptotic giant branch stars that have been extracted from primitive meteorites and conclude that such grains required approximately 100,000 years to grow to their observed sizes ($\sim 10 - 25$ microns). We are now investigating processes that would allow such grains to remain suspended in AGB atmospheres for such long time scales.

3.2 Hydrocarbon Chemistry in the Atmospheres of Jupiter and Saturn

Photochemical models of the atmospheres of Jupiter and Saturn indicate that a major loss process of ethyl radicals in the atmospheres of these two giant planets is the reaction $\text{H} + \text{C}_2\text{H}_5$. The models further suggest that the reaction channel $\text{H} + \text{C}_2\text{H}_5 \rightarrow 2 \text{CH}_3$ is a significant source of methyl radicals in these atmospheres. The methyl radical has recently been observed in the atmospheres of Saturn and Neptune. A search of the chemical literature reveals that there are two relatively modern kinetic studies of the $\text{H} + \text{C}_2\text{H}_5$ reaction but both of these investigations involve extensive modeling of eight elementary reactions in order to obtain a rate constant. The lack of direct, absolute determinations of the rate constant for this reaction at low temperatures and pressures has motivated L. J. Stief, A. S. Pimentel, W. A. Payne, F. L. Nesbitt, and R. J. Cody to initiate a flow-discharge, mass spectrometric measurement of the rate constant at temperatures and pressures appropriate for use in outer planet models. The investigation will also seek to identify the products and branching ratios of the reaction.

Hydrogen atoms and ethyl radicals are simultaneously generated by reaction of fluorine atoms with mixtures of H_2 and C_2H_6 . The rate constant is determined under pseudo-first order conditions by following the decay of C_2H_5 in an excess of H atoms. Results thus far at $P = 1$ Torr yield $k(298\text{K}) = 1.13 \times 10^{-10} \text{ cm}^3 \text{ molecule}^{-1} \text{ s}^{-1}$ and $k(202\text{K}) = 1.18 \times 10^{-10} \text{ cm}^3 \text{ molecule}^{-1} \text{ s}^{-1}$. Experiments at $T = 155 \text{ K}$ are in progress.

3.3 Nitrile Chemistry in Titan's Atmosphere

Cyanoacetylene ($\text{H}-\text{C}\equiv\text{C}-\text{CN}$) has been observed in the atmosphere of Titan by ground-based observations and by instruments aboard the Voyager spacecraft. Models of Titan's atmosphere, i.e. the 1984 model of Yung, Allen and Pinto and the 1995 model of Toubanc, et al. calculate mixing ratios for HC_3N that are vastly different from direct observations. An important loss process for HC_3N in the named models is the three body reaction $\text{H} + \text{HC}_3\text{N} + \text{M} \rightarrow \text{C}_2\text{H}_2\text{CN}$. The rate constant for this reaction has never been measured. The models assume a value equal to that measured for the reaction $\text{H} + \text{C}_2\text{H}_2 + \text{M} \rightarrow \text{C}_2\text{H}_3 + \text{M}$. Co-investigators, R. J. Cody, J. K. Parker (Catholic University of America), W. A. Payne and L. J. Stief have used the experimental technique of discharge flow coupled with collision-free sampling to a mass spectrometer to monitor the decay of cyanoacetylene in excess H atoms at nominal pressures of $P = 0.5, 1.0$ and 2.0 Torr (He) and $T = 298, 250$

and 200 K in order to measure first order rate constants for the reaction. The bimolecular rate constants were derived from slopes of plots of k_{1st} versus $[\text{H}]$. The results indicate that, over the limited pressure range and within the experimental uncertainty, there is no pressure dependence of the bimolecular rate constant at $T = 298 \text{ K}$. This suggests that the rate constant has reached its high-pressure limit by 1 Torr for $T \leq 298 \text{ K}$. The rate constants are $k(298 \text{ K}) = 2.1 \times 10^{-13}$, $k(250 \text{ K}) = 1.5 \times 10^{-13}$, $k(200 \text{ K}) = 0.93 \times 10^{-13}$, all in units of $\text{cm}^3 \text{ molecules}^{-1} \text{ s}^{-1}$. These rate constants can be fit by the Arrhenius expression $k = 1.1 \times 10^{-12} \exp(-500/T) \text{ cm}^3 \text{ molecules}^{-1} \text{ s}^{-1}$. These measured rate constants are about a factor of 50 greater than those estimated by analogy with $\text{H} + \text{C}_2\text{H}_2$ and have a much weaker temperature dependence. *Ab initio* calculations have been performed at the G2M and CCSD(T)/6-311G(d,p) levels of theory with the hope of better understanding the temperature dependence of the reaction. The use of our experimental data for the $\text{H} + \text{HC}_3\text{N}$ reaction is expected to have a large impact on the calculated atmospheric abundance of HC_3N in Titan's atmosphere.

3.4 Cosmic Ice Experiments

High Energy Particles and UV Photons Continuously Create and Destroy Compounds on The Jovian Moons. Members of the Laboratory examined both UV and ion (proton) processing of ices relevant to the sulfur and carbon cycles of Europa, Callisto, and Ganymede. Infrared signatures for H_3O^+ , HSO_4^- , SO_4^{2-} ions were stable in 100 K ices, but resulted in hydrated H_2SO_4 after warming above $\sim 200 \text{ K}$. Both the formation and destruction of H_2SO_4 was examined. In addition CO_3 and CO formation in H_2O ices containing CO_2 are predicted.

Prediction of New Molecules Awaiting Detection on Titan. Recent Laboratory work shows that CN-containing molecules, already known on Titan from earlier NASA missions, can undergo UV- and cosmic-ray promoted reactions, even at very low temperatures. It was shown that acetonitrile (H_3CCN) (known Titan molecule) easily rearranges to form H_2CCNH . In addition, experiments show that if H_2O is present then HCN or CN^- can form OCN^- , another good candidate molecule for space- and ground-based observations. Of interest to astrobiologists is the possibility of pyrimidine formation from an organic nitrile HCCCN (known Titan molecule) and OCN^- (a predicted Titan molecule if H_2O is present).

Evasive Molecule Stabilized at Low Temperatures. The IR spectrum of vinyl alcohol ($\text{CH}_2\text{CH}(\text{OH})$) was identified in both proton irradiated and UV photolyzed ices containing $\text{H}_2\text{O} + \text{C}_2\text{H}_2$. Vinyl alcohol is considered to be an unstable, intermediate step in the formation of other products. At low temperature, however, vinyl alcohol is formed and is stable. These results may explain the origin of interstellar vinyl alcohol.

Radiation Products Relevant to EKB Objects. Members of the Astrobiology Branch studied radiation chemi-

cal products of N₂-rich and H₂O-rich ices containing CO or CH₄ (e.g. volatiles such as alcohols, acids, and bases). Spectra from 1 to 5 microns of carbon suboxide, carbonic acid, the ammonium and cyanate ions, polyoxymethylene, and ethylene glycol were measured for these less-volatile products that could accumulate on EKB objects.

3.5 Astrobiology

GSFC Center for Astrobiology. NASA's Astrobiology Institute (NAI) selected a team of scientists led by GSFC for a five-year, multimillion-dollar research effort that will explore how organic molecules are created in interstellar clouds and delivered to planets as they form. The overall objective is to discover if comets supplied the raw material for the origin of life on Earth, and whether similar processes could have occurred elsewhere. M. Mumma is Principal Investigator (PI) for the NAI Goddard Node.

The NAI research led by Goddard capitalizes on the Team's strengths in laboratory astrochemistry, planetary systems research, interstellar, stellar, planetary, and cometary spectroscopy, and spacecraft instrument development. The Center for Astrobiology will focus on four Themes:

Theme 1: Establish the taxonomy of icy planetesimals and their potential for delivering pre-biotic organics and water to the young Earth and other planets. Theme 2: Investigate processes affecting the origin and evolution of organics in planetary systems. Theme 3: Conduct laboratory simulations of processes that likely affected the chemistry of material in natal interstellar cloud cores and in proto-planetary disks. Theme 4: Develop advanced methods for the in-situ analysis of complex organics in small bodies in the Solar System.

The interdisciplinary team includes more than 40 researchers in Earth science, space science, and instrument development. Institutions with scientific co-investigators include the University of Maryland (College Park), the California Institute of Technology, the Johns Hopkins University Applied Physics Laboratory, the SETI institute, Washington University (St. Louis), Eckerd College, the University of Massachusetts (Amherst), and the University of Washington (Seattle). Institutions with scientific collaborators include the Carnegie Institution of Washington, NASA's Ames Research Center, The University of California at Santa Cruz, The Catholic University of America, and Rowan University. International collaborators include scientists from the University of Paris (France), and Leiden Observatory (The Netherlands). For more information about the Goddard Center for Astrobiology on the Internet, and links to the individual scientists, visit: <http://astrobiology.gsfc.nasa.gov/>.

The NASA Astrobiology Institute is an international research consortium with central offices located at NASA's Ames Research Center in California's Silicon Valley. NASA Ames is the Agency's lead center for astrobiology, the search for the origin, evolution, distribution and future of life in the universe. For more information about the NAI on the Internet, visit:

<http://nai.arc.nasa.gov/>.

Astrobiology and Organics in Interstellar Ices. J. Dworkin (hired to the Astrochemistry Branch in September 2002) has worked with M. Mumma (PI) and his team of 20 Co-investigators (from the Laboratory for High Energy Astrophysics, Laboratory for Astronomy and Solar Physics, Laboratory for Extraterrestrial Physics, Laboratory for Atmospheres, and Laboratory for Terrestrial Physics) to propose and win a NASA Astrobiology Institute node for GSFC. The 5-year project will begin November 2003. He has also written or co-authored seven other proposals to the Office of Space Science to win funding for the construction, equipping, and staffing of a new laboratory for analytical chemistry of ices, grains, and meteorites for astrobiology.

In addition, J. Dworkin has completed several papers related to his work while an employee of the SETI Institute at NASA Ames Research Center. These are primarily concerned with the synthesis of biologically significant compounds (e.g. amino acids) from laboratory simulations of UV processed realistic interstellar or pre-cometary ices.

4 PLANETARY SCIENCE

4.1 Solar Eclipse Studies

Solar Eclipse Predictions. In November 2002, F. Espenak authored NASA TP-12002-211618 titled "Annular and Total Solar Eclipses of 2003." This publication contains complete details for each eclipse including tables, maps, figures and meteorological statistics for viewing sites. The NASA eclipse bulletins are prepared in cooperation with the IAU Working Group on Eclipses as a public service to both the professional and lay communities, including educators and the media. The publication is also available on the web at: <http://umbra.nascom.nasa.gov/eclipse/2003/rp.html>.

Espenak's annual contribution "Eclipses During 2004" was published in the Royal Astronomical Society's Observer's Handbook. A second article, "The 2004 Transit of Venus" was published in the same publication.

F. Espenak was an invited speaker at several conferences. At the Hands on the SUN Workshop in Tucson, Arizona (Nov. 2002), Espenak spoke on "The Dynamic Sun and Eclipses" and "Eclipse Predictions for 2003 and Beyond." At the Winter Star Party in Florida (Feb. 2003), the topic was "Predictions for the 2003 Annular and Total Solar Eclipses." During Ireland's Whirlpool Star Party (Sept. 2003), the presentation title was "The Next Decade of Solar Eclipses."

5 PLANETARY OBSERVATIONS

5.1 Planetary and Cometary Physics

Atmospheric investigations of Mars by the Goddard group of the Mars Global Surveyor Thermal Emission Spectrometer Experiment (TES) team continued. The MGS spacecraft completed its 20,000th orbit on August 29, 2003. More than 2 1/2 martian years of infrared spectral observations have been obtained during the map-

ping mission. Analysis of data taken in the limb-viewing mode have been analyzed by M.D. Smith and M. Kaelberer of GSFC, and B. J. Conrath of Cornell University, yielding temperature profiles from the surface to 65 km. Scientific interpretation of these results is underway.

Major effort has continued for the Cassini Composite Infrared Spectrometer (CIRS) experiment. Planning of observations for the four-year orbital tour of Saturn that begins July 1, 2004, continues.

5.2 Venus

Venus Ionosphere. Earlier studies of the Venus lower ionosphere by J. Grebowsky and D. Pesnell indicated that a prominent ionization layer due to meteoroids was not likely. However a further theoretical analysis now shows that the value of the eddy diffusion coefficient, which controls the low altitude ion distribution profile, can be sufficient to yield a metal ionization layer with peak density comparable to those seen by the Pioneer Venus Orbiter radio occultation measurements below 130 km.

Venus Pick-up Ions. Direct observations of pick-up ion processes, in the region where the extended atmosphere of Venus interacts with the shocked solar wind, have yet to fully delineate the properties of the pick-up ion cyclotron trajectories and their plasma wave signatures. New studies of the Venus energetic ion measurements and magnetic field wave activity from Pioneer Venus Orbiter measurements (undertaken by Hartle, Grebowsky, Intriligator and Crider) have now shown that ion cyclotron wave activity in association with accelerated energetic ions of ionospheric origin is apparently only present in the far tail of the planet. Near the planet there is no evidence that ions of atmospheric origin are ever accelerated to pick-up ion energies or have the complete cycles of gyration needed for wave stimulation.

5.3 Mars

Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES). M. Smith has been using MGS/TES infrared spectra to monitor the seasonal and spatial variations of atmospheric temperatures, aerosols, and water vapor. There are now over two full Martian years of data from MGS. In the past year, Smith has documented the amount of interannual variability in atmospheric temperature and aerosol optical depth between results from the first and second Martian years of MGS mapping. He found that there was much more interannual variability in the perihelion season ($L_s=180-360$) than in the aphelion season ($L_s=0-180$), and that the redistribution of surface dust caused by the planet-encircling dust storm of 2001 resulted in an overall cooling in daytime surface and atmospheric temperatures that persisted for at least a full Martian year after the storm. Smith has also used TES limb-geometry spectra to study the scattering properties and the vertical distribution of dust and water-ice aerosols and water vapor gas.

Mars Odyssey Thermal Emission Imaging System.

M. Smith is a Participating Scientist for the Mars Odyssey mission. He has been using Thermal Emission Imaging System (THEMIS) thermal infrared data to retrieve dust and water ice aerosol optical depth as a function of time and location on Mars. The orbit of Mars Odyssey is at a different local time than MGS and provides atmospheric information complementary to that of MGS TES. Smith finds that although dust optical depth is essentially the same between observations during the early afternoon (MGS/TES) and early evening (Odyssey/THEMIS), ice optical depth is substantially higher in the evening than in the early afternoon.

Mars Mesospheric Non-thermal Emission. W.

Maguire and A. Kutepov (NAS/NRC) began modeling non-LTE (non-local thermodynamic equilibrium) contributions to Mars 15 micrometer CO_2 band, which is used for temperature inversion. In general, until now, the atmosphere has been assumed to be in LTE when performing these inversions. This assumption is still valid for nadir observations, which sample principally the lower part of the atmosphere which is in LTE. Above about 85 km, however, this band is no longer in thermal equilibrium. In their modeling of MGS/TES limb observations, even at limb-tangent altitudes below this height, non-LTE contributions to the observed radiance have been calculated to be significant. This modeling is important because temperatures in the upper atmosphere affect Martian dynamics and climate. They are formulating a forward-fitting routine to account for these effects in future temperature inversions.

Mars Atmosphere and Surface. D. Glenar and Co-investigators G. Bjoraker, J. Pearl, M. Smith, D. Blaney (JPL), G. Hansen (PSI) and D. Klassen (Rowan Univ.) are conducting multiple-season, spectral imaging measurements of Mars at near-IR wavelengths (2-4 microns), using the IRTF/SpeX and NSF/CAM. The properties of aphelion season clouds ($L_s=130$) have been mapped over a full-hemisphere, complementing the restricted local-time coverage of MGS/TES. These results provided near-IR optical depths, both for convection clouds and the diffuse aphelion cloud band. Data acquired during the '01 opposition show the spatial distribution of optical depth within dust storm 2001A, and measurements during the '03 opposition are providing both low altitude temperatures as well as the large-scale distribution of CO_2 ice properties within the (diminishing) south polar cap.

Stability of Mars CO_2 Atmosphere: Seasonal variability of Ozone. K. Fast, a co-op student, is continuing research into the role of ozone in the stability of Martian CO_2 against ultraviolet photolysis, using infrared heterodyne measurements to directly sample ozone spectral features from Mars, Doppler-shifted into narrow intervals of high atmospheric transmission between counterpart telluric features. Ozone is an important tracer of the CO_2 reformation process on Mars involving products of water photolysis. Infrared absorption lines of ozone observed in heterodyne spectra taken during many different Martian seasons are being analyzed to investigate

ozone and water anticorrelation and to compare with CO₂ reformation models. Calibration spectra acquired to evaluate transmission through the Earth's atmosphere provide important information about Earth ozone profiles, and the results of this passive measurement technique are being compared to measurements using active means such as lidar, ozonesonde releases, etc. New measurements with the Heterodyne Instrument for Planetary Wind and Composition (HIPWAC) were obtained in June 2003 with advisor T. Kostiuk, T. A. Livengood, J. Annen, and G. Sonnabend. Initial results indicate greater ozone abundance in the south polar region than in the northern low latitudes on Mars. Additional measurements will be made in October-November 2003.

Physics of Mars Non-LTE CO₂ Emission.

T. Kostiuk, with Co-investigators T. A. Livengood, W. C. Maguire, J. Pearl, K. E. Fast, and T. Hewagama, are supporting MGS/TES observations that have detected and spatially mapped non-thermal emission by CO₂ in the upper atmosphere of Mars, previously identified in infrared heterodyne measurements in the 1970's and 80's. TES does not spectroscopically resolve the individual CO₂ emission lines and thus does not have direct access to physical information about the source region in Mars' mesosphere, at about 65–85 km altitude. The CO₂ emission feature appears at the core of absorption features due to pressure-broadened CO₂ in the troposphere, silhouetted against thermal emission by Mars' surface. The FWHM of the emission line is about 20 MHz at a frequency of 25.5×10^6 MHz (~ 851 cm⁻¹), requiring resolving power significantly greater than $\lambda \nu \Delta \lambda = 10^6$ to resolve the shape of the CO₂ emission feature. HIPWAC measurements in August 2001 at resolving power $\lambda \nu \Delta \lambda = 5 \times 10^6$ determined the gas kinetic temperature in the source region from the Doppler line-broadening of non-LTE ro-vibrational CO₂ lines. Positions along the 2PM dayside track of the MGS orbit were observed so that data directly complement MGS/TES measurements of the emission intensity. Temperatures range from 125 K to 200 K in 2001. Observations in June 2003 probe the same Mars seasonal phase as August 2001. Preliminary mesospheric temperatures range from 110 K to 170 K, depending on latitude. Disc center spectra from 2001 show variability in the altitude of dust mixing, signified by changing depth in the tropospheric absorption feature. Higher mesospheric temperatures in the 2001 data may bear some relationship to the dust storm at the time, surprising since dust surely does not mix so high as the mesosphere. Initial results from the 2003 program were reported at the 2003 Division of Planetary Sciences (DPS) Meeting.

Mars Global Surveyor (MGS). The Mars Global Surveyor spacecraft has recently finished the first two Martian years of science operations (2 x 687 days) in circular polar orbit about Mars. The science payload includes a Magnetometer and Electron Reflectometer (Mario Acuña, Principal Investigator) to measure the magnetic field and plasma in the near space environment of Mars. The magnetometer and flight processor

was built at GSFC and the Electron Reflectometer was provided by the CESR in Toulouse, France, under the direction of Henri Rème and in collaboration with colleagues at the University of California at Berkeley. The investigation continues to acquire data throughout the (extended) mapping phase of the mission, at approximately 400 km altitude, and fixed (2am - 2pm) local time.

Previous findings of the MGS MAG/ER Investigation include the discovery and characterization of many crustal magnetic anomalies scattered about and within the crust of Mars, the outer shell of the planet's surface with a thickness of a few tens of km to perhaps 100 km. Nearly the entire surface has been mapped with extraordinary signal fidelity (100's), revealing crustal anomalies at least an order of magnitude greater in intensity of magnetization than those on earth (Connerney et al., 2001; Acuña et al., 2001). Large regions of the crust are intensely magnetized (e.g., southern highlands) and large regions appear essentially non-magnetic (e.g., Utopia and Isidis Planitia, Northern lowlands, Hellas and Argyre impact basins), revealing a 'magnetic dichotomy' associated with the crustal dichotomy in elevation, crater density, and surface morphology that has been a mystery for decades. These Martian crustal magnetic anomalies are presumed to be the relics of an early (now extinct) Mars global magnetic field, produced by dynamo action in the planet's interior. GSFC researchers are M. H. Acuña, J. E. P. Connerney, P. Wasilewski, and G. Kleteschka.

5.4 Jupiter

Atmospheric Composition. G. Bjoraker and

C. Nixon analyzed spectra of Jupiter's atmosphere acquired by Cassini/CIRS during the Jupiter flyby in December 2000. Two products of the collision of comet Shoemaker-Levy 9 with Jupiter in 1994 were still detectable 6 years later: HCN and CO₂. Jupiter spectra were divided into 10-degree latitude bins. Large scale averages of CIRS spectra at a spectral resolution of 0.3 cm⁻¹ were produced. The stratospheric temperature profile was retrieved and synthetic spectra were calculated to fit the observed emission lines of HCN and CO₂. The HCN abundance peaks at 45 degrees south - precisely the latitude of the impacts. Interestingly, CO₂ peaks near the South Pole. This unusual spatial distribution requires a combination of photochemistry and dynamical transport. This work was presented at the 2003 meeting of the DPS in Monterey, California.

M. Wong and G. Bjoraker modeled CIRS spectra of NH₃ clouds on Jupiter. This resulted in the first detection of NH₃ ice on Jupiter in the thermal infrared. CIRS maps of Jupiter reveal the presence of NH₃ ice near 23 degrees North and near the Equator. This technique is sensitive to 1-micron size particles in Jupiter's upper troposphere. These results were submitted and accepted in the Planetary and Space Science journal.

P. Romani together with C. Nixon and other members of the CIRS science team in interpreting observa-

tions of the meridional variations of C_2H_2 and C_2H_6 in Jupiter's Atmosphere. Preliminary results indicate that the meridional transport time on Jupiter is quicker than the ethane (C_2H_6) photochemical lifetime but slower than the acetylene (C_2H_2) photochemical lifetime. In addition the stagnant region at the tropopause must extend into stratosphere to approximately the 25 mbar region to explain the high C_2H_6 abundance. A paper for publication in *Icarus* is in preparation.

Continuing Studies of Jovian Mid-IR Aurora. New infrared heterodyne observations of auroral emissions by ethane in Jupiter's atmosphere were obtained in January of 2003 by T. Kostiuk with Co-investigators T. A. Livengood, F. Schmölling, D. Buhl, K. E. Fast, and T. Hewagama using HIPWAC. This work continues the study of long- and short-term variability of mid-IR auroral emission extending back to the *Voyager* epoch. Data obtained in December 2000 and in February 2001, during the Cassini spacecraft flyby of Jupiter, has been analyzed and incorporated into the long term data record. Results complement space-based measurements by the *Cassini* Composite Infrared Spectrometer (CIRS) and show more modest increase in the measured ethane emission compared to previous ground based and *Voyager* IRIS results near periods of solar maximum. Both ethane abundances and thermal structure were obtained for the auroral regions and globally for the 2000–2001 data, with similar retrievals in progress for the 2003 data.

Jupiter Observing Program. A long-term Jupiter observing program is conducted at NASA's IRTF (Infrared Telescope Facility) at Mauna Kea, HI, by Connerney and Satoh (Kumamoto Univ., Japan). This program, begun in 1992, acquires images of Jupiter at a wavelength of 3.4 microns in the IR, revealing the global distribution of bright emission from H_3^+ ions against a disc otherwise darkened by methane absorption below the homopause. These emissions reveal variations due to the solar wind interaction with Jupiter's magnetosphere as well as aurorae and other emissions related to the electromagnetic interaction between Jupiter's moon, Io, and the Jovian magnetic field.

5.5 Saturn

Cloud Structure. G. Bjoraker and N. Chanover (New Mexico State Univ.) acquired 5-micron spectra of Saturn using the SpeX instrument on NASA's Infrared Telescope Facility in Hawaii. Saturn's 5-micron spectrum has 2 components: thermal emission from the 5-bar level and reflected sunlight from the 400 mbar level. Spectra of the South Pole and of the Equatorial Zone were modeled. The South Pole is substantially darker than the Equator. This can be explained by changes in the albedo of the cloud layer at 400 mbars rather than by changes in the transmittance of deeper cloud layers. These results were presented at the Monterey DPS Meeting in September 2003.

Saturn, Long Term Support of the Cassini Mission. T. Kostiuk, T. A. Livengood, K. E. Fast, P. N. Romani, J. Annen, and G. Sonnabend, with H. U. Käuff

(ESO), are continuing the study of ethane abundance and stratospheric thermal structure on Saturn using infrared heterodyne spectroscopy. Data consist of ethane line emission spectra near 12 μm wavelength acquired at the NASA IRTF from 1989 to 1999 and broadband spectrophotometric images acquired in 1996 with TIMMI at the European Southern Observatory 3.6-m telescope. Additional measurements will be acquired in November 2003 using HIPWAC. The high spectral resolution permits constraints on both ethane abundance and stratospheric temperature. The meridional distribution of ethane mole fraction and stratospheric temperature is obtained from globally distributed measurements as well as from the spectrophotometric imaging data. Temporal changes are observed over the 11-year period corresponding to one-third of Saturn's year. Significant difference in the spectral features is observed in mid-Summer high North latitudes and mid-Spring high South latitudes. A warmer temperature and a lower ethane abundance were retrieved from the southern measurements. Results will be complementary to expected data that will be acquired by the Composite Infrared Spectrometer (CIRS) on the Cassini spacecraft starting in 2004.

5.6 Titan

Titan Aerosols. N. Chanover and C. Anderson (New Mexico State), C. McKay (NASA/Ames), C. Rannou (Univ. Paris), D. Glenar, J. Hillman, and W. Blass have examined Titan haze properties using multi-spectral adaptive optics measurements at the Mt. Wilson 2.5 m natural-guide-star adaptive optics telescope. The science camera used in this study was a GSFC-built acousto-optic tunable filter (AOTF) camera. Measurements within the 940 nm methane "window" and model comparisons suggest removal of haze by rainout in the equatorial region. A new multi-spectral AOTF camera is being developed at NMSU for additional measurements of Titan haze properties, to be conducted at the Maui 3.67 m telescope.

5.7 Neptune

Triton Ionosphere. Expanding upon the known importance of meteoroids on the lower ionosphere and upper atmospheres of the terrestrial planets, D. Pesnell and J. Grebowsky have pointed out for the first time that meteoroids can have a significant impact in the very rarified atmosphere of Triton, the large moon of Neptune. Besides leaving significant traces of ionized and neutral metal species in the atmosphere, they discovered that bright meteor trails extending to the immediate vicinity of the moon's surface will illuminate Triton's sky.

Mid-Infrared Spectroscopy of Neptune. T. Hewagama, T. Kostiuk, P. Romani, and T. Livengood are collaborating with H. Hammel (SSI) on detailed modeling of Hammel's 3–13 micron wavelength observations of Neptune obtained with the Broadband Array Spectrograph System (Aerospace Corp.) at the NASA/IRTF. Initial modeling of the ν_9 ethane band emission suggests that the abundance of ethane is under-

estimated in current photochemical models. There are discrepancies between the data and spectra constructed through radiative-transfer modeling using thermal and photochemical profiles derived from *Voyager* spectroscopic and occultation data. The data are being used to constrain modifications to the *Voyager*-epoch profiles. Modified profiles can be tested against archival infrared heterodyne spectra obtained during the *Voyager* epoch as well as directly comparing to *Voyager* measurements, to determine whether the modifications diagnose a secular change or identify complexity overlooked in earlier analyses.

5.8 Extra Solar Planets

Study of Extra-Solar Planetary Systems. D. Deming and J. Richardson continued their search for the secondary eclipse of the “transiting planet,” HD209458b. Analysis of 2-micron spectra taken at the IRTF (SpeX), in collaboration with S. Seager (CIW/DTM) has placed the strongest limit to date on the flux from the planet. In collaboration with J. Harrington (Cornell Univ.) and Seager, they have obtained 3.8-micron photometry during secondary eclipse from the IRTF. The photometric data are being analyzed together with 4-micron spectroscopy in an attempt to detect a predicted flux peak from the planet at this wavelength. They are also collaborating with J. Harrington and P. Rojo (Cornell Univ.) in an attempt to detect water vapor absorption from the atmosphere of this planet during transit. Spectra from IRTF and Keck/NIRSPEC are currently being analyzed for possible planetary water vapor absorption.

D. Deming and J. Richardson are collaborating with T. Brown (HAO), D. Charbonneau (Caltech) and J. Harrington (Cornell Univ.) to attempt detection of carbon monoxide in the atmosphere of HD209458b using transit spectroscopy from Keck/NIRSPEC. Preliminary analysis of the data shows sufficient sensitivity to expect detection of CO at levels predicted by some plausible models of the planet’s atmosphere.

T. Hewagama with Co-investigators R. Barclay, T. Chen, D. Deming, C. Goukenleuque, M. Greenhouse, R. Henry, M. Jacobson, B. Mott, S. Satyapal, and D. Schwinger reported on their work on “Spectral Contrast Enhancement Techniques for Extrasolar Planet Imaging,” at the Scientific Frontiers of Research in Extra-Solar Planets Meeting held in Washington D.C. in June 2002. Extrasolar planet imaging techniques for future missions which involve shaped and apodized pupil coronagraphy were discussed. These techniques may be enhanced by exploiting the extrasolar planets spectral signature, which shows contrast between particular spectral regions. Frequency switching techniques, based on such spectral contrast, as potential methods for improving the imaging capability of pupil plane optimized systems are also being studied. A follow-up paper also was presented at the SPIE meeting held in Hawaii in August 2002.

5.9 Asteroids and Comets

The Organic Composition of Comets. M. J. Mumma

reviewed the group’s cometary research program [Mumma et al. 2002, Mumma et al. 2003]. To date, organic volatiles and water in eight Oort cloud comets were investigated at infrared wavelengths. The detected parent species include H_2O , CO, CH_3OH , CH_4 , C_2H_2 , C_2H_6 , OCS, HCN, NH_3 , and H_2CO . Several daughter fragments (CN, OH, NH_2 , etc.) are also measured. OH prompt emission provides a useful proxy for water when H_2O itself is not measured, and preliminary results of its study (B. Bonev, Ph. D. thesis topic) were presented (Bonev et al. 2003). Long-slit spectra are taken at high spectral dispersion and high spatial resolution, eliminating many sources of systematic error. The resulting parent volatile production rates are highly robust, permitting a sensitive search for compositional diversity among comets. For six comets, data reduction is complete. Five exhibit similar compositions (excepting CO and CH_4), and also agree with comet Halley. Their low formation temperatures (30K) suggest this group probably formed beyond 30 AU from the young sun. However, a sixth OC comet, C/1999 S4 is severely depleted in hypervolatiles and also in methanol, and it likely formed near 5-10 AU. A seventh comet is enriched in hypervolatiles. This represents the first clear evidence for compositional diversity among comets that formed in the giant-planets’ region of the protoplanetary disk.

OH Prompt Emission in Comets. Multiplets from OH in the 1-0 band were seen in prompt emission throughout the 2.9 - 3.7 μm wavelength range in several comets observed with NIRSPEC at the W. M. Keck Observatory. These emissions originate from vibrationally-excited rotationally-hot states of OH, produced by dissociative excitation of water. B. P. Bonev, M. J. Mumma, N. DelloRusso, E. L. Gibb, M. A. DiSanti, and K. Magee-Sauer reported results (Bonev et al. 2003) for the OH quadruplet falling near 3046 cm^{-1} at the 2003 DPS meeting. They presented line-by-line g-factors in comets C/1999 H1 (Lee), C/2001 A2 (LINEAR), and C/2000 WM1 (LINEAR) based on relative OH line intensities and comparison with simultaneous production rate measurements of the parent (H_2O).

Comet C/2002 C1 (Ikeya-Zhang). M. J. Mumma, N. DelloRusso, M. A. DiSanti, K. Magee-Sauer, and E. L. Gibb investigated the composition of C/2002 C1 Ikeya-Zhang at infrared wavelengths. This Oort-cloud comet was discovered in Feb. 2002, and Target-of-Opportunity time was awarded at the NASA IRTF in March and April post-perihelion [UT 2002 March 21.9 (Rh = 0.51 AU) and April 13.9 (Rh = 0.78 AU)]. The comet was unusually bright, rivaling comet Hyakutake during its close approach to Earth. Our long-slit spectra featured both high spectral dispersion and high spatial resolution about the nucleus, permitting the extraction of rotational temperatures, production rates, and spatial information along the slit. Water (H_2O), methane (CH_4), acetylene (C_2H_2), ethane (C_2H_6), hydrogen cyanide (HCN), ammonia (NH_3), carbon monoxide (CO), methanol (CH_3OH), and formaldehyde (H_2CO) were detected. On UT April 13.8, $Q(\text{H}_2\text{O}) = (2.1 \pm 0.3)$

$\times 1029$ molecules s⁻¹, and $Q(\text{C}_2\text{H}_6) = (1.3 \pm 0.2) \times 1027$ molecules s⁻¹, giving a mixing ratio of $\text{C}_2\text{H}_6/\text{H}_2\text{O} = (6.2 \pm 1.3) \times 10^{-3}$. Also, the absolute production rates for HCN and C_2H_2 were $(3.8 \pm 0.5) \times 1026$ molecules s⁻¹ and $(3.7 \pm 0.8) \times 1026$ molecules s⁻¹, on that date, yielding mixing ratios $\text{HCN}/\text{H}_2\text{O} = (0.18 \pm 0.04) \times 10^{-2}$ and $\text{CH}_3\text{OH}/\text{H}_2\text{O} = (2.5 \pm 0.5) \times 10^{-2}$, on UT April 13.8. For the 3-day mean April 11 - 13, $\text{H}_2\text{CO}/\text{H}_2\text{O} = (0.62 \pm 0.18) \times 10^{-2}$ [DiSanti et al. 2002]. Our retrieved rotational temperature for CO (115 ± 8 K) was based on the intensities of eight lines. The spatial profiles for all three species was consistent with release solely from the nucleus. The chemistry of comet Ikeya-Zhang was consistent with that of five other Oort cloud comets (excepting CO).

Search for HDO in Comets. E. L. Gibb, M. J. Mumma, M. A. DiSanti, N. DelloRusso, and K. Magee-Sauer searched for HDO emission in our infrared database of six Oort Cloud comets (C/2002 C1 (Ikeya-Zhang), C/2001 A2 (LINEAR), C/2000WM1 (LINEAR), C/1999 H1 (Lee), C/1999 S4 (LINEAR), and C/1999 T1 (McNaught-Hartley)) [Gibb et al. 2002]. Spectral lines of the n1 fundamental vibrational band of HDO were sampled using high-resolution infrared spectra acquired with both CSHELL at the NASA IRTF and NIRSPEC at the W. M. Keck Observatory. Of these comets, the recent apparition of the bright comet Ikeya-Zhang, with its high gas production rate and good geocentric Doppler shift, provided an exceptional opportunity to search for minor constituents such as HDO. HDO was tentatively detected in three comets and upper limits were determined for the remaining three. These data, combined with future observations, will be used to test models of nebular chemistry and delivery of water and organics to the early Earth.

Methane in Comets. E. L. Gibb, M. J. Mumma, N. DelloRusso, M. A. DiSanti, and K. Magee-Sauer reported CH_4 abundances in eight Oort cloud comets using a fluorescence model they developed for the n3 band [Gibb et al. 2003]. New g-factors for the R0 and R1 lines were given for representative rotational temperatures in cometary comae, and resulting CH_4 production rates and mixing ratios were presented. Relative abundances of CH_4 and CO were compared, and no correlation was found among the comets sampled, suggesting that thermal conditions alone did not control hyper-volatile abundances in these comets.

Comet C/1996 B2 (Hyakutake). M. J. Mumma, M. A. DiSanti, N. DelloRusso, K. Magee-Sauer re-analyzed their observations of comet C/1996 B2 Hyakutake using algorithms and procedures developed during their Hale-Bopp campaign. The initial reductions were based on nucleus-centered extracts only, and they neglected optical depth effects. The revised analyses are based on spatial profiles about the nucleus, and they include corrections for optical depth in the CO pump along with various other improvements and minor corrections. Their long-slit infrared spectra featured both high spectral dispersion and high spatial resolution about the nucleus,

permitting the extraction of rotational temperatures, production rates, and spatial distributions of species along the slit. The spatial distributions of C_2H_6 , HCN, and H_2O in the coma were consistent with their release directly from the nucleus, although asymmetries about the nucleus were seen for both gas and dust. CO showed a small distributed-source contribution.

Production rates were measured for water (on four dates) and ethane (on three dates) between UT 1996 March 23.4 (Rh = 1.08 AU) and April 12.2 (Rh = 0.64 AU pre-perihelion) [DelloRusso et al. 2002]. Their average relative abundance was $\text{C}_2\text{H}_6/\text{H}_2\text{O} = (6.2 \pm 0.7) \times 10^{-3}$. HCN was detected on UT 1996 March 24.4 (Rh = 1.06 AU, D = 0.106 AU); a Boltzmann analysis of eight ro-vibrational lines in the n3 band returned a rotational temperature (83 ± 9 K) for a region centered on the nucleus [Magee-Sauer et al. 2002]. The global HCN production rate was $(4.50 \pm 0.81) \times 1026$ molecules s⁻¹, and its abundance relative to water was (0.18 ± 0.04) . The measured spatial distribution for HCN was consistent with its release at the nucleus - no significant contribution from a distributed source is required within ~ 600 km of the nucleus.

Carbon monoxide was measured on four pre-perihelion dates (UT 1996 March 24.5 - April 12.2), providing the first secure ground-based detection of cometary CO at infrared wavelengths [DiSanti et al. 2003]. The retrieved rotational temperatures are consistent with a heliocentric dependence $T_{\text{rot}} = 63 \text{ Rh}^{-1.06} \text{ K}$ over the range Rh = 1.06 - 0.64 AU. From long-slit analyses, native and distributed sources of CO were distinguished, and the relative abundance of native to total CO was inferred to be 0.773 ± 0.054 on April 12.2. If the ratio is constant on UT April 11.2 and 12.2, the mixing ratios (relative to water) are 0.149 ± 0.019 for native CO and 0.191 ± 0.022 for the sum of native and extended sources. The scale for release of the extended source observed on UT 1996 April 12.2 is consistent with that observed for C/1995 O1 (Hale-Bopp) on UT 1997 January 21, after taking into account the difference in heliocentric distance assuming insolation-limited release. This may suggest a similar progenitor material in the two comets.

6 SUN-EARTH CONNECTIONS

6.1 Magnetospheric Physics

Magnetosphere Magnetic Field Modeling. N. Tsyganenko has continued research in the area of the data-based modeling of the Earth's magnetosphere. The most recent work focused at the derivation of a global quantitative model of the nightside magnetotail current sheet. In a joint study with D. Fairfield, an analytical approximation was developed for the shape of the current sheet, representing it as a function of the Earth's dipole tilt angle, solar wind ram pressure, and the interplanetary magnetic field (IMF). The model was based on 5-min magnetometer data of the Geotail and Polar spacecraft, spanning the periods 1994-2002, and 1999-2001, respectively. All the data were tagged by concurrent values

of the solar wind pressure and IMF By and Bz components. Warping and twisting parameters were calculated by minimizing the number of mismatches between the observed and predicted orientation of the magnetic field on both sides of the model current sheet. The model is valid within the nightside magnetosphere down to tailward distance of 50 R_E . It was found that variations of the solar wind pressure change the shape of the deformed current sheet in such a way that an increase of the pressure results in a decrease of the magnetotail “hinging distance,” but increases the magnitude of its transverse warping. The IMF Bz affects the magnitude of the seasonal/diurnal motion of the current sheet in the north-south direction, and it also controls the degree of the IMF By-related twisting, which becomes much larger during the periods with northward IMF Bz.

The data-based modeling of the magnetosphere was a central topic of the recent AGU Chapman Conference on the Physics and Modeling of the Inner Magnetosphere, held in August 2003 in Helsinki, Finland. The Conference was convened and organized jointly by T. Pulkkinen (Finnish Convener) and N. Tsyganenko (US Convener).

Forecasting the Radiation Belt Environment. A radiation belt - ring current forecasting model, also called a Radiation Belt Environment (RBE) model, has been developed by M.-C. Fok, Y. Zheng (USRA) and G. V. Khazanov at NASA/MSFC. This is one of the ongoing projects of the University Partnering for Operational Support (UPOS) program, which is sponsored by the U.S. Air Force and the U.S. Army, involving collaboration between NASA (GSFC and MSFC), Universities (UAK and JHU), and other government agencies (AFRL). The ultimate goal of this project is to develop a model that can predict the radiation belt environment and the corresponding radiation doses, 24 hours ahead of time. The model is a data-driven physics-based model, which solves the bounce averaged convection-diffusion equation of plasma distribution functions in the ranges of 2-12 earth radii and 10 keV to 5 MeV energy. The effects of fluctuating magnetic and electric fields in particle transport, energy and pitch-angle diffusions due to wave-particle interactions are included in the model. A plasmasphere model is also embedded in the forecasting model to specify the cold plasma distribution for wave diffusion coefficient calculations. The only input to the model are solar wind and IMF conditions, which real-time data (ACE data) are available to be downloaded from the NOAA ftp site. The first version of the RBE model is now running in real time and provides nowcasting of energetic electron fluxes and pitch-angle distributions every 15 minutes. Information about the model and the model results are posted at the URL: <http://sd-www.jhuapl.edu/UPOS/RBE/index.html>.

Cavity Mode Resonances. Toroidal and poloidal oscillations of the geomagnetic field have been interpreted in terms of resonant oscillations excited by variations in the solar wind dynamic pressure and the Kelvin-Helmholtz instability on the Earth’s magnetopause. Be-

cause ground stations often observe identical frequencies over a range of latitudes, global ‘cavity’ mode models are often invoked. D. G. Sibeck is currently reexamining previously reported examples of cavity mode resonances to determine whether they can be directly attributed to foreshock-generated pressure pulses propagating through the magnetosphere.

Morphology of the Ring Current. G. Le in collaboration with C. T. Russell (UCLA) and K. Takahashi (JHU/AP) have been analyzing over twenty years of *in situ* magnetic field measurements in the entire volume of the inner magnetosphere with multiple spacecraft, including ISEE (1977-1987), AMPTE/CCE (1984-1989), and currently operational Polar (1996-present). The large magnetic field dataset allows them for the first time to quantify how the ring current flows and closes in a self-consistent manner. Using intercalibrated magnetic field data from the three spacecraft, they are able to construct the statistical magnetic field maps and derive 3-dimensional current density by the simple device of taking curl of the magnetic field. In general, *in situ* observations show that the ring current varies as the Dst index decreases as we would expect it to change. An unexpected result is how asymmetric it is in local time. Some current clearly circles the magnetosphere but much of the energetic plasma stays in the night hemisphere. During quiet times, the symmetric and partial ring currents are similar in strength (~ 0.5 MA) and the peak of the westward ring current is close to local midnight. It is the partial ring current that exhibits most drastic intensification as the level of disturbances increases. Under the condition of moderate magnetic storms, the total partial ring current reaches ~ 3 MA whereas the total symmetric ring current is ~ 1 MA. As the ring current strengthens, the peak of the partial ring current shifts duskward to pre-midnight sector. The partial ring current is closed by a meridional current system through the ionosphere, mainly the field-aligned current, which maximizes at local times near the dawn and dusk. The closure currents flow in the sense of region-2 field-aligned currents, downward into the ionosphere near the dusk and upward out of the ionosphere near the dawn.

The Dusk Flank of the Magnetosphere under Northward IMF Conditions. D. Fairfield has been investigating an interval of steady northward IMF on January 10-11, 1997, using Geotail and Interball spacecraft data at X=-5 to -15 R_E on the dusk flank of the magnetosphere which revealed magnetopause boundary layer motions caused by both solar wind pressure discontinuities and the Kelvin-Helmholtz instability. Several large, sudden changes in solar wind density caused the magnetopause to move across both spacecraft. Relative timing of these crossings along with corresponding geosynchronous and ground magnetic field changes showed that a wave in the boundary layer propagates down the tail faster than the causal pressure front moves tailward in the magnetosheath. This situation can cause the boundary to bulge out in the region ahead of the magnetosheath front. The tailward convecting magnetosheath

pressure front also moves more slowly near the magnetopause than it does further out in the magnetosheath, thus distorting the front and enhancing the likelihood that the boundary layer wave will outrun the magnetosheath front. Integrating the velocity perpendicular to the boundary shows that the boundary waves can have amplitudes of at least 1 or 2 Re. When the solar wind was steady, boundary waves were observed with periods of several minutes that are consistent with excitation of the Kelvin-Helmholtz instability. Magnetograms from 5 ground magnetometer chains show both pulsations initiated by the pressure discontinuities and ongoing wave trains probably related to the KH instabilities. A paper has been submitted for publication.

ISIS Digital Database. Digital ISIS 1 topside-sounder ionograms continue to be produced, from the original analog telemetry tapes, by a team led by R. F. Benson. Approximately 400,000 digital ISIS-1&2 ionograms covering the 15-year interval from early 1969 through early 1984 have been archived at the National Space Science Data Center at GSFC. Programs to assist in the retrieval of the data, to produce electron-density profiles from the echo traces, and to help interpret sounder-stimulated ionospheric plasma resonances are available from their web site (<http://nssdc.gsfc.nasa.gov/space/isis/isis-status>). Work with V. Osherovich has stressed the importance of applying the scientific knowledge gained from these active ionospheric soundings to magnetospheric physics and astrophysics.

Plasma Physical Models of Self-organized Criticality in the Magnetotail Plasma Sheet. V. Uritsky (St. Petersburg State Univ.), A. J. Klimas, D. Vassiliadis, and D. N. Baker (Univ. of Colorado), through a study of the evolution of bright nightside auroral emission regions in long sequences of Polar UVI images, have shown that the occurrence probabilities of several physical properties of the emission regions are governed by scale-free power-law distributions over remarkably large ranges of scales. Further, using a superposed epoch analysis, they have shown that the average spreading and decay rates of the emission regions exhibit signatures of critical dynamics. Taken together, these two results show that the UV auroral emission regions evolve statistically in exactly the same manner as avalanches in sand-pile models of self-organized criticality (SOC). The most straightforward and, at present, sole explanation for this result is SOC in Earth's magnetotail plasma sheet. A simulation study is in progress to guide a proposed *in situ* study of the plasma sheet dynamics. Driven 1-D and 2-D current-sheet models are under consideration at present. An important characteristic of these current-sheet models is strong coupling between resistive MHD phenomena at large scales and resistivity generating kinetic phenomena at small scales. The bursty, intermittent Poynting flux in these models has been shown to exhibit scale-free power-law distributions over large ranges of scales with power-law indices close to those found by Uritsky *et al.* [2002] in their analysis of the auroral image data.

On Substorms during Prolonged Northward IMF. In

a paper by C.-C. Wu, K. Liou, R. P. Lepping, G. Le, and C.-I. Meng (2002) giving examples of observations of substorms during prolonged northward IMF, based on WIND/MFI and SWE data, it was reported, for the first time, clear evidence of substorms that occurred during a long-lasting "ground state" of the magnetosphere (i.e., where $Kp < 0+$ for more than 16 hours). For the two reported substorm events there was no clear evidence for substorm triggering by either IMF directional changes or by solar wind dynamic pressure increases, indicating that these substorms were occurred more spontaneously than by being triggered.

On Substorms within Geomagnetic Storms. In a paper by C.-C. Wu, K. Liou, R. P. Lepping, and C.-I. Meng (2003b) on the identification of substorms within geomagnetic storms it was found that: (1) auroral breakups occurred more frequently in the main phase than in the recovery phase within the storms, (2) storm intensity (Dst) does not affect the occurrence of auroral breakup (substorm onset), and (3) changes in Dst have no effect on the occurrence frequency of auroral breakup.

Modeling of Collisionless Magnetic Reconnection. M. Hesse, M. Kuznetsova, and J. Dorelli used kinetic simulations of collisionless magnetic reconnection to study the effect on the reconnection rate of ion density enhancements in the inflow region. The goal of the investigation was to study a candidate mechanism for the slow-down of magnetic reconnection. The calculations involved either proton or oxygen additions in the inflow region, initially located at two distances from the current sheet. Protons are found to be much more tightly coupled into the evolution of the reconnecting system and therefore to effect an immediate slowdown of the reconnection process, as soon as the flux tubes they reside on become involved. Oxygen, on the other hand, has, within the limits of the calculations, a much less pronounced effect on the reconnection electric field. The difference is attributed to the lack of tight coupling to the magnetic field of the oxygen populations. Last, a study of proton and oxygen acceleration found that protons respond primarily to the reconnection electric field, whereas the main oxygen electric field is accomplished by Hall-type electric fields at the plasma sheet boundary.

They have investigated the physics of driven magnetic reconnection at the terrestrial subsolar magnetopause using analytical and numerical approaches by solving the magnetohydrodynamics (MHD) equations. Their approach to this problem has been divided into two areas: 1) investigations of the effects of Hall electric fields on the physics of flux pileup antiparallel magnetic field annihilation, 2) assessment of the relevance of analytical flux pileup solutions of the MHD equations for global MHD simulations of driven reconnection at the terrestrial subsolar magnetopause. Their research has demonstrated that MHD predicts significant pileup of magnetic energy in the terrestrial magnetosheath under steady southward IMF conditions. Further, they have shown that Hall-induced flux pileup saturation (as predicted by analytical annihilation solutions) is probably

not sufficient to account for the experimentally observed lack of flux pileup at the magnetopause under southward IMF conditions.

Plasma Transport and Energization. Two new efforts in the study of plasma transport and energization were initiated by T. E. Moore, M.-C. Fok, and W. Allen during 2003. First, they visited R. M. Winglee at the Univ. of Washington for an introduction to his multifluid magneto-dynamic (MMD) simulation code and transferred a copy of the code to GSFC to be run locally. Currently the only magnetospheric global simulation to include separate solar and terrestrial atmospheric fluids, this code will be used in future work to set up numerical experiments complementary to the ongoing work at UW. Their first experiment was to study a magnetosphere characteristic of the central phase of a geomagnetic field reversal, when the tilt angle of the field reaches 90° and the dipole axis lies nearly in the ecliptic plane. The MMD code successfully simulated this rather extreme change of boundary conditions, for typical solar wind conditions. Second, they developed a database tool to handle large numbers of individual particle trajectories in the magnetosphere, as computed by the Delcourt 3D particle propagator code. This allows the accumulation of local particle properties in a 3D grid of spatial bin. It supports examination of particle velocity distributions in any bin and calculation of bulk parameters throughout the simulated magnetosphere. Initial tests of this tool have been run for photothermal ionospheric outflows (polar wind) and for magnetosheath entry via the low latitude boundary layer.

Planetary Radio Bursts. R. A. Hess and R. J. MacDowall studied interplanetary scattering at low frequencies ~ 100 kHz using Jovian radio emissions observed in the Ulysses spacecraft data. The magnitude of the scattering was found to vary with wavelength as expected from analytic theory; however, there is considerable scatter from event to event, due to variations in the intervening density and density fluctuations.

6.2 Heliospheric and Solar Physics

ROSAT X-ray Observations of the Primary and Secondary Streams of Interstellar Neutral Atoms. A team from the LEP which includes M. R. Collier, T. E. Moore, D. Simpson and B. Pilkerton along with S. Snowden from the Laboratory for High Energy Astrophysics and additional investigators from other institutions is examining soft X-ray (~ 0.25 keV) emission resulting from solar wind charge exchange with interstellar neutral atoms. Preliminary results from the RASS indicate a value of α consistent with about 6×10^{-16} eV cm², a heliospheric contribution to the total X-ray flux ranging from about 18% at about five-ten degrees off the downstream axis to about 40% directly above the downstream axis viewing southward, and a secondary stream entering the heliosphere from above the ecliptic plane about ten degrees higher in ecliptic longitude than the primary stream.

Search for the Source of Mysterious Bursty Magnetic Field Wave Activity at 1 AU and Throughout the Helio-

sphere. A team of investigators from LEP which includes M. R. Collier, A. Roberts and A. Szabo along with scientists from other institutions is examining low frequency electromagnetic wave activity with periods near the proton cyclotron frequency to determine the origin of this activity. Possible sources to be examined include, but are not limited to, neutral atoms of terrestrial origin, neutral atoms related to ICMEs or other solar activity, interstellar neutral atoms and dynamic turbulent cascade processes.

A Statistical Study of Interplanetary Shocks and Pressure Pulses Internal to Magnetic Clouds. Using magnetometer data from the Wind spacecraft, M. R. Collier, R. P. Lepping and D. Berdichevsky have performed a statistical study of pressure pulses and interplanetary shocks internal to magnetic clouds. In the 68 clouds examined, these internal shocks and pressure pulses occur in nine or about 13% of the Wind magnetic clouds. These internal shocks and pressure pulses tend to occur in the latter half of the clouds, i.e. time-wise, about two-thirds of the way through.

2D-MHD Model of the Solar Wind. E. Sittler as Principal Investigator for a SOHO Guest Investigator NRA has been using the semi-empirical MHD model of the solar wind by Sittler and Guhathakurta (1999, 2002) to develop a self-consistent 2D MHD model of the solar wind. This model does not assume a polytrope, which is violated near the Sun, and uses an empirically determined effective heat-flux to constrain the solutions. Preliminary results are very promising showing multiple streamers converging to a singular equatorial streamer as observed. Multiple streamer topologies are also likely. They are presently performing an error analysis of the solutions from which they can fit analytical functions to 2D maps of effective temperature and heat-flux (by “effective” they mean the possible presence of waves). The use of analytical functions are expected to provide numerical stability and speed up convergence in their solutions. A conference paper by Sittler et al. (2003) for the Solar Wind X Conference in Pisa Italy in 2002 was accepted for publication. In preparation for Stereo they have developed a 3D model of the coronal density using Legendre polynomials. They can generate 2D maps of coronal brightness from 3D coronal streamers and are in the position to generate movies of the coronal brightness as the Sun rotates. This effort was done by a student from MIT under the MIT Externship program with E. Sittler as mentor. They are also developing a semi-empirical model of the solar wind electrons using the Krook’s approximation for the collision term (wave scattering and Coulomb collisions) and solving Boltzmann’s equation. Then using our empirical model, radial temperature maps from SOHO and Ulysses they will be able to provide 2D maps of the electron heat flux, interplanetary potential and electron distribution function. The zeroth order electron distribution function is assumed to be a Kappa distribution.

Electron Distribution at Interplanetary Shocks. R. J. Fitzenreiter, K. W. Ogilvie and A. F. Viñas and other

colleagues have analyzed a small selection of interplanetary shocks of moderate strength, observed by instruments aboard the WIND spacecraft. They find electron signatures of heating and acceleration that are similar to those found at Earth's high Mach number bow shock. Upstream, velocity distributions have the signature of shock-accelerated electrons with the characteristic time of flight velocity cutoff with bump-on-tail reduced distributions observed in coincidence with Langmuir waves. Downstream, the distributions broaden with the stronger shocks showing flat-topped distributions and accompanying beams, such as are seen on the high entropy side of Earth's bow shock. They apply the Liouville mapping analysis of *Hull et al.* [1998, 2001] to one of the interplanetary shocks and compute the deHoffman-Teller electrostatic potential across the shock using the electron moments to map the observed upstream distribution to the downstream region. The mapping successfully reproduces the inflated phase density and beam signatures of the observed downstream electron velocity distribution.

Foreshock Electrons: Vlasov Simulations. A. F.-Viñas, in collaboration with J. A. Miller (Univ. of Alabama-Huntsville), and A. J. Klimas have developed, as a result of recent numerical algorithm advances, a numerical simulation code to solve self-consistently the filtered and un-filtered Vlasov-Maxwell equations directly, to investigate the evolution of particle distribution functions in the solar wind electron foreshock. As a result of this new initiative they have written a tutorial paper on the construction of such simulation to solve specifically the one-dimensional electrostatic Vlasov-Poisson equations, which describe a rich and wide range of plasma phenomena. The resulting simulation is more than a factor of 100 times faster than the corresponding particle simulation, and yields almost noiseless particle distribution functions. A paper has been submitted to the *Am. J. Phys.* in 2003.

The Nature of Sun-Earth Connections During Solar Maximum. D. B. Berdichevsky, R. P. Lepping, K. W. Ogilvie, M. L. Kaiser and other colleagues, investigated the coalescence of ejecta in the heliosphere. Their study discussed the essential similarities and differences of two intervals of extreme interplanetary solar wind conditions, separated almost precisely by two solar cycles, in April 1979 and March-April 2001. The similarities extend to various data-sets: energetic particles, solar wind plasma and interplanetary magnetic field. In April 1979 observations were made by three spacecraft covering a wide longitudinal range ($\sim 70^\circ$) in the heliosphere. Data are presented from Helios 2, located 28° East of the Sun-Earth line at ~ 2 -3 AU, and from near the Earth. Observations of the 2001 interval are from Wind. They also examined the geomagnetic activity during each interval and presented more than one month of the corresponding radio, energetic particles, and solar wind parameters collected with the Wind spacecraft.

Interplanetary Shock Geometry in the Magnetosheath. A. Szabo, in collaboration with C. W. Smith

(Bartol Research Institute, University of Delaware) and R. Skoug (LANL) continued their multi-spacecraft analysis of the interplanetary shock surface curvature. The study focused specially on the geometry of interplanetary shocks in the Earth's magnetosheath. New Cluster data and MHD simulation results suggest that the transmitted pressure pulses of weaker interplanetary shocks suffer some geometrical deformation in the magnetosheath. This result is significant for accurate space weather forecasting of interplanetary shock induced geomagnetic activities.

Earth's Bow Shock. A. Szabo, in collaboration with J. King (GSFC), J. D. Richardson and J. Merka have been analyzing all of the Earth bow shock crossings observed by the IMP 8 spacecraft. All 28 years of the mission has been completely analyzed and the completed database is being placed in a publicly searchable database at NSSDC. This large database was compared to the predictions of the most popular bow shock models and a surprisingly large degree of deviation was found implying the need to update and improve the current bow shock models.

Invited Review Paper. R. Lepping was invited to present a review chapter on the solar wind's role in Space Weather in a book by Research Signpost, Trivandrum, India, in a series called Recent Research Developments in Astrophysics. The chapter is entitled "Sun-Earth Electrodynamics: The Solar Wind Connection." It provides some background to the subject and concentrates on the recent work by a team in LEP studying transient interplanetary structures, magnetic clouds, and their solar and geomagnetic connections, and balances this with discussion of the importance of quasi-periodic solar wind structures, all under the umbrella of Space Weather. The book was recently published in 2003. D. Berdichevsky, C-C. Wu, R. Fernandez Borda, and A. Szabo contributed significantly to the review.

Estimating Errors on Magnetic Cloud Fit Parameters. R. Lepping, D. Berdichevsky and T. Ferguson recently developed a process to estimate errors in force-free magnetic cloud model fit-parameters employing a Monte Carlo technique to simulated magnetic clouds composed of two parts: (1) exactly simulated cloud fields and (2) added "noise." The noise level, to have realistic structural characteristics, was developed from actual magnetic clouds from WIND observations. A paper on this by these authors is now in press. The results provided a better understanding of the limitations of the cloud-fitting program being used and showed specifically that the order of estimated accuracy of the cloud fit parameters (from best to worst) usually was: diameter, axial field magnitude, symmetry, axial direction, and closest approach distance. The study further gave a practical scheme for using the results to help estimate errors on these fit-parameters in future studies. Recently, extrapolation and interpolation of the results have been added to increase the technique's effectiveness, and a program is now being developed to automate the process for any realistic case. This represents the first time such error

analysis has been implemented in a production mode in a cloud fitting program.

Program for Predicting Geomagnetic Storms in Real-time due to North-to-South Types of Magnetic Clouds. R. Lepping and C-C. Wu are developing a program by which it will possible to predict the Dst geomagnetic index based on real-time measurements of a magnetic cloud (MC), with a north-to-south type of internal IMF-Bz, passing Earth, as well as from guidance from previously modeled MCs from WIND observations. The scheme should be applicable to ACE data, for example. The program consists of five stages: (1) identification of the proximity of a cloud-complex, (2) estimating the MC's front boundary and 'center time,' (3) predicting the speed and minimum IMF-Bz and the latter's timing within the MC, and (4) estimating the associated Dst, based on reliable IMF-Bz vs. Dst relations from well-known previous work. Such north-to-south types of MCs are expected to be most common in the near future.

Program to Automatically Identify Interplanetary Magnetic Clouds. R. Lepping and C-C. Wu have developed a computer program automated to identify objectively an interplanetary magnetic cloud (MC) by examining proton plasma beta, degree of smoothness of the magnetic field's directional change, and field strength, for any reasonably continuous data set of these quantities; these are criteria consistent with a MC's definition. The scheme has been applied to WIND MCs over the period 1995 through 2002, in order to determine its ability to identify MCs of any type when compared to well-know MCs. It rarely produces false positives and apparently can sometimes find MCs that were not found previously, but these are usually difficult to analyze structurally, probably representing 'shallow' passes of the spacecraft.

Exact MHD solutions. D. B. Berdichevsky, R. P. Lepping, and C. J. Farrugia have investigated the essential differences in the nature of the evolution of two analytical solutions describing magnetic flux tubes evolving in time. The first solution maintains the elongation of the tube, while the second maintains a constant angular extension with respect to a possible point-like source. In the first case, free-expansion of the plasma (density N) occurs only in a direction perpendicular to the flux tube x -axis. In the second case, isotropic evolution is considered. In both cases it is assumed that at initial time t_0 the flux tube B-field is the force-free magnetostatic Lundquist solution, which energetically corresponds to the most stable state for any flux tube structure. They showed that for each case conservation of magnetic flux is enough to establish the scaling with time of the B-field. While both expansions correspond to the evolution of observed flux tubes in the heliosphere, the isotropic expansion appears to capture consistently essential features associated with the actual observations of expanding coronal mass ejections within thirty solar radii. For isotropic expansion of the plasma the force-free nature of the B-field is preserved for all time. As an example, the MHD solutions are applied to an interplanetary magnetic cloud observed with the spacecraft Wind, which

passed Earth's vicinity on June 2, 1998.

Shock and Discontinuities Analysis Tool (SDAT). A. F. Viñas with the collaboration of M. Holland (GSFC/Code 587) have developed an analysis/visualization tool to study shocks and other discontinuities from satellite observations of plasma and magnetic field data. The analysis is based on extensions to the Viñas-Scudder method published in JGR/1985. SDAT was developed in IDL, but a version rewritten in Tcl/Tk with the assistance of Chris Gurgiolo (Bitterroot Basic Research) has also been developed. As currently configured, SDAT reads ASCII data from any space mission for the analysis. All data displays and graphics generated by SDAT are written in Postscript and a summary of the analysis is generated as an ASCII file. The tool allows for data zooming in time and the input data can be in any coordinate system. Some other utilities necessary for the decimation of data at different resolution and merging has also been developed to compliment the SDAT tool. Examples of real satellite data are included to facilitate the learning process in the usage of the tool. This tool is available to the Space Physics community. To learn more about SDAT or get a copy version, contact A. F. Viñas at adolfo.vinas@gsfc.nasa.gov.

Multi-ion Component in the Fast Solar Wind. A. F.-Viñas in collaboration with J. Araneda and H. Asudillo (Univ. of Concepcion, Chile) have investigated typical non-thermal features of the ion velocity distribution functions observed in the fast solar wind in connection to ion heating by wave-particle processes. Among these non-thermal feature are the relative streaming between two proton components, an alpha/proton relative flow, and anisotropic proton cores temperatures with $T_{\perp i} > T_{\parallel i}$ (subscripts are directions relative to the background magnetic field B_0). Their analytical and simulation studies indicate that all these non-thermal features leads to the growth of the several electromagnetic instabilities. A major result found was that for conditions typical of the fast solar wind and for parallel propagation, the proton core temperature anisotropy plays a significant role in modifying the wave-particle scattering of each ion component as compared to the isotropic case. Such an effect leads to a reduction in both the heating and anisotropy enhancement of the proton beam and alpha component and to a decrease in the relative proton/proton and proton/alpha flow speeds below the corresponding isotropic instability thresholds. This result provides additional support to the physical scenario in which instability thresholds agree with observable constraints on plasma species anisotropies and match closer recent solar wind observations by the WIND/SWE Faraday Cup measurements and also the Ulysses measurements.

Solar Wind Quasi-invariant. J. Fainberg and V. Osheovich continue to study the solar wind quasi-invariant (QI, ratio of magnetic energy density to the kinetic energy density in the solar wind) in two directions: 1) QI as a heliospheric index of solar activity (from 0.7 to 28 AU) and 2) QI anomaly (increase by factor of > 20)

as an indicator of magnetic clouds and related magnetic storms. The multi-tube topology of interplanetary magnetic clouds is another current research area (with modeling and observations). Research is also underway on self-similar nonlinear Langmuir oscillations with a goal of interpretation of the spectra electric field fluctuations related to type III solar radio bursts as well as disturbances located in front of the Earth's bow shock.

Solar Radio Bursts. T. Golla and R. J. MacDowall have investigated various aspects of the interplanetary extensions of solar radio bursts. Various aspects of Langmuir waves produced by energetic electrons from flares were studied, including evidence for Langmuir collapse in type III burst source regions. Type II radio emission, produced by electrons from coronal or interplanetary shocks, is frequently observed to be highly fragmented. Mechanisms involving mode conversion at sharp gradients in density were examined and found likely to contribute to fragmented emissions. An unusual wave event at 5 AU was determined to provide evidence of electrostatic decay of the Langmuir waves.

Modeling the Heliosphere in Three Dimensions. A. Usmanov and M. Goldstein continue the development a two- (axisymmetric) and three-dimensional MHD code and have incorporated an improved numerical algorithm (Total Variation Diminishing (TVD) Lax-Friedrichs with the Woodward limiter). They have also implemented a new algorithm to maintain the divergence-free constraint for the magnetic field. The 2D and 3D MHD codes have been re-written with the Message Passing Interface (MPI) to take advantage of parallel computing environments. With these codes, the variation in solar wind magnetic field, density, velocity, and temperature observed during the first fast south-north transition of Ulysses have been modeled. A quadrupole has been added to the solar surface magnetic field allow investigation of the effect of non-axisymmetric solar magnetic on the solar wind velocity and magnetic fields. The simulations agree very well with the Wang-Sheeley empirical model which relates the areal expansion factor of the magnetic field near the Sun and solar wind speed observed at Earth's orbit. This work provided the first confirmation of the Wang-Sheeley ideas using simulations. The simulations support the interpretation that when very low densities are observed in the solar wind, they are often associated with the trailing edges of higher-speed streams and they tend to appear in between faster wind streams. During all events with extremely low densities (0.2 cm^{-3} or less), the solar wind became sub-Alfvénic for varying time intervals. They concluded that the low density anomalies are produced by slow flows that emerge into preexisting fast wind, in particular during solar polar field reversals. The MHD simulations have supported the hypothesis that a very strong rarefaction ($n < 0.1 \text{ cm}^{-3}$) can develop behind fast flow followed by slow flow. The low density events are sometimes discussed in the context of Coronal Mass Ejections (CMEs). Their simulations show that strong density depletions may be formed as a result of a pro-

cesses not associated with CMEs.

MHD Simulation of Large- and Intermediate-Scale Nonlinear Solar Wind Processes. Spatial inhomogeneity and temporal variability near the Sun produce a highly nonuniform solar wind. Spacecraft studies show that this nonlinear medium is evolving and producing, for example, shocked stream interaction regions, turbulent cascades, and possible vortex streets. M. Goldstein and D. A. Roberts, working with A. Deane of the University of Maryland, are now performing 3-D MHD simulations of the solar wind in spherical geometry, including a wide variety of phenomena such as stream shear, wave, two-dimensional turbulence, microstreams, and magnetic pressure balance structures. The simulations now reproduce much of the observed behavior, such as strong spectral evolution near current sheets and shear layers and the formation of the expected interaction regions. New insights include the realization that nonlinear effects do not return either wave vectors or magnetic fields in the way required by some simple models of the fluctuations, and that the observed two-dimensional correlation function for interplanetary fluctuations can be reproduced by sheared waves in an expanding geometry. On the global scale, the simulations have revealed that it is difficult to keep the two heliospheric magnetic sectors separated, and that loop-like "connection" fields should be common. This conclusion is supported by Helios data at heliospheric current sheet crossings. Much more complex patterns, supported by data analysis, result when a rotating current sheet is combined with shear and waves. The effects causing the connection field may be important for other phenomena, such as where rigidly rotating coronal holes are sheared by differential rotation. These results are reported in the proceedings of the *Solar Wind 10* conference, and in the regular literature.

Coronal Mass Ejections and Solar Polarity Reversal. N. Gopalswamy, A. Lara, S. Yashiro, and R. Howard found a close relationship between the solar polarity reversal and cessation of high-latitude CMEs. This result holds good for individual poles of the Sun for two cycles – 21 and 23, for which CME data are available. The high-latitude CMEs provide a natural explanation for the disappearance of the polar crown filaments (PCFs) that rush the poles. The PCFs, which are closed field structures, need to be removed before the poles could acquire open field structure of the opposite polarity. Inclusion of CMEs along with the photospheric and sub-photospheric processes completes the full set phenomena to be explained by any solar dynamo theory.

Coronal Mass Ejections of Solar Cycle 23. N. Gopalswamy, A. Lara, S. Yashiro, and others studied the solar cycle variation of various properties of CMEs, such as daily CME rate, mean and median speeds, and the latitude of solar sources for cycle 23 (1996-2002). They find that (1) there is an order of magnitude increase in CME rate from the solar minimum (0.5/day) to maximum (6/day), (2) the maximum rate is significantly higher than previous estimates, (3) the mean and median speeds of CMEs also increase from minimum to maximum by

a factor of 2, (4) the number of metric type II bursts (summed over Carrington Rotations) tracks CME rate, but the CME speed seems to be only of secondary importance, (5) for type II bursts originating farther from the Sun the CME speed is important, (6) the latitude distribution of CMEs separate the prominence-associated (high-latitude) and active-region associated CMEs, and (7) the rate of high-latitude CMEs shows north-south asymmetry and the cessation eruptions in the north and south roughly mark the polarity reversals. They compared the rates of the fast-and-wide CMEs, major solar flares, interplanetary (IP) shocks, long-wavelength type II bursts and large SEP events. This comparison revealed that the number of major flares is generally too large compared to all the other numbers. In other words, fast-and-wide CMEs, long-wavelength type II bursts, large SEP events, and IP shocks have a close physical relationship.

Prominence Eruptions and Coronal Mass Ejections. N. Gopalswamy, M. Shimojo, W. Lu, and others performed a statistical study of a large number of solar prominence events (PEs) observed by the Nobeyama Radioheliograph. They studied the association rate, relative timing and spatial correspondence between PEs and CMEs. They classified the PEs as radial and transverse, depending on whether the prominence moved predominantly in the radial or horizontal direction. The radial events were faster and attained a larger height above the solar surface than the transverse events. Out of the 186 events studied, 152 (82%) were radial events, while only 34 (18%) were transverse events. Comparison with white-light CME data revealed that 134 (72%) PEs were clearly associated with CMEs. They compared their results with those of other studies involving PEs and white light CMEs in order to address the controversy in the rate of association between CMEs and prominence eruptions. They also studied the temporal and spatial relationship between prominence and CME events. The CMEs and PEs seem to start roughly at the same time. There was no solar-cycle dependence of the temporal relationship. The spatial relationship was, however, solar cycle dependent. During the solar minimum, the central position angle of the CMEs had a tendency to be offset closer to the equator as compared to that of the PE, while no such effect was seen during solar maximum.

Coronal and Interplanetary Environment of Large Solar Energetic Particle Events. N. Gopalswamy, S. Yashiro, G. Stenborg, and R. Howard studied the CMEs properties associated with large solar energetic particle (SEP) events during 1997-2002 and compared them with those of preceding CMEs from the same source region. The primary findings of this study are (1) High-intensity (> 50 protons/(sqcm.s.sr)) events are more likely to be preceded by other wide CMEs. (2) The preceding CMEs are faster and wider than average CMEs. (3) The primary CMEs often propagate through the near-Sun interplanetary medium severely disturbed and distorted by the preceding CMEs. (4) The occurrence rate of the SEP events, long-wavelength type II bursts and the fast and

wide frontside western hemispheric CMEs is quite similar, consistent with the scenario that CME-driven shocks accelerate both protons and electrons; major flares have a much higher rate. (5) The SEP intensity is better correlated with the CME speed than with the X-ray flare class. They also used a specific event to demonstrate that preceding eruption from a nearby source can significantly affect the properties of SEPs and type II radio bursts.

Effect of CME Interaction on the 1-AU Arrival Time of Interplanetary Shocks. P. Manoharan, N. Gopalswamy, A. Lara, and others have studied a large number of CMEs and their associated interplanetary (IP) shocks for the period 1996-2002, using white-light images from SOHO/LASCO and solar wind measurements from SOHO's Mass Time-of-Flight spectrometer (MTOF) and Solar Wind Experiment (SWE on the Wind spacecraft). The 1-AU arrival times of the CMEs shocks are obtained from by the inputting the initial speed of CMEs into empirical models developed by Gopalswamy et al. (2001). One of the primary objectives of this study is to assess the influence of preceding CMEs on the propagation of IP shocks. It was found that the propagation characteristics of some of the fast CMEs and their shocks are modified by the interaction with the preceding CMEs. Accordingly, the arrival times of IP shocks show deviation from those of the non-interacting CMEs.

A Statistical Study of CMEs Associated with Metric Type II Bursts. A. Lara, N. Gopalswamy, S. Nunes, and others studied the characteristics of CMEs which show temporal association with type II bursts in the metric domain but not in the decameter/hectometric (DH) domain. This study is based on a set of 80 metric (m) type II bursts associated with solar-surface events in the solar western hemisphere. It was found that in general, the distribution of the widths and speeds of the CMEs associated with metric (but not DH) type II bursts are shifted towards higher values compared to those of all CMEs observed by LASCO in the 1996-2001 period. They also found that these distributions have lower values than the same distributions of the CMEs associated with DH type II bursts. In terms of energy, this means that the CMEs associated only with metric type II bursts are more energetic (wider and faster) than regular CMEs but less energetic than the CMEs associated with DH type II bursts.

Type II Radio Bursts and Energetic Solar Eruptions. Type II radio bursts at decameter-hectometric (DH) and kilometric wavelengths are indicative of CME-driven shocks in the interplanetary medium. Only a subset of these type II bursts continue from the DH to the km regimes. N. Gopalswamy, S. Nunes, S. Yashiro, and R. Howard recently concluded a study of these long-lasting type II bursts using data from the Wind/WAVES experiment in conjunction with white-light CME data from SOHO. They found that the majority of these events (80%) are also associated with metric Type II bursts. The associated CMEs were found to be the most energetic of all CMEs. There seems to be a hierarchy

of CME energies, progressively increasing in association with metric type II bursts, DH type bursts and the long-lasting type II bursts.

Relationship Among CMEs, Flares and Type II Radio Bursts. N. Gopalswamy, A. Rosas, M. L. Kaiser, and others are investigating all the type II bursts observed by Wind/WAVES until the end of 2002. These bursts correspond to interplanetary shocks forming within a few solar radii distance from the Sun. Each one of these type II bursts was associated with a large-scale white-light CME. The onset times of CMEs extrapolated to the solar surface using height-time plots were compared with the onset times of the type II bursts in the metric and decameter-hectometric (DH) domains. Similarly, the onset times of flares were also compared with the onset times of the radio bursts. Distributions of various time differences indicate that the type II bursts and CMEs (not) flares are more closely associated. This suggests that the shocks responsible for type II bursts may all be CME-driven.

Coronal Streamer Changes and Prominence Eruptions. N. Gopalswamy, M. Shimojo, W. Lu, and others investigated white-light coronal streamers as pre-eruption configurations of CMEs. Coronal streamers overlie prominences and often possess all the substructures of CMEs. They studied a set of prominence eruptions associated with streamer changes with no obvious CMEs. The streamer changes and microwave prominence eruptions were observed by the Nobeyama radioheliograph and Solar and Heliospheric Observatory (SOHO), respectively. Multiwavelength data showed that at least one of the streamer events involved heating and small-scale material ejection that subsequently stalled. After presenting illustrative examples, they compare the properties of the streamer-related events with those of general population of prominence events. They find that the properties of streamer-related prominence events are closer to those of prominence eruptions with transverse trajectories. They concluded that the partial filament eruptions occur frequently and may serve as the mechanism by which streamers distend before erupting as CMEs.

Narrow CMEs. S. Yashiro, N. Gopalswamy, G. Michalek, and R. A. Howard investigated the statistical properties of narrow CMEs (CMEs, angular width are $< 20^\circ$) with particular emphasis on comparison with normal CMEs. They investigated 806 narrow CMEs from the online LASCO/CME catalog (<http://cdaw.gsfc.nasa.gov/CME.list>) and found that (1) the fraction of narrow CMEs increases from 12% to 22% towards solar maximum, (2) during the solar maximum, the narrow CMEs are generally faster than normal ones, (3) the maximum speed of narrow CMEs (1141 km/s) is much smaller than that of the normal CMEs (2604 km/s). These results imply that narrow CMEs do not form a subset of normal CMEs and have a different acceleration mechanism from normal CMEs.

New Method for Measuring the Properties of Halo CMEs. It is well known that coronagraphic observations

of halo CMEs are subject to projection effects. Viewing in the plane of the sky makes it difficult to determine the crucial parameters such as the space speed, width and source location. Assuming that halo CMEs have constant velocities and that they are symmetric and propagate with constant angular widths, G. Michalek, N. Gopalswamy, and S. Yashiro developed a technique which allows to obtain the required parameters. This technique requires measurements of sky-plane speeds and the moments of the first appearance of the halo CMEs above opposite limbs. They applied this technique to obtain the parameters of all the halo CMEs observed by the SOHO mission's Large Angle and Spectrometric Coronagraph (LASCO) until the end of 2002. One of the important finding is that the space speed is only 20% larger than the sky-plane speed.

The CDAW Data Center. The CDAW data center is a repository of information on geoeffective solar events such as CMEs. This data center maintains a number of specialized data bases such as the Living With a Star (LWS) CDAW data base on solar energetic Particle events and the campaign events for the SHINE 2003 workshop. The data base is open to public and the basic objective is to provide value-added data products from NASA missions to enhance the scientific return. The SOHO mission's LASCO have detected more than 7000 CMEs from its launch in 1995 until the middle of 2003. These CMEs are identified, measured and cataloged online and made available to the scientific community from http://cdaw.gsfc.nasa.gov/CME_list.html. S. Yashiro, N. Gopalswamy, G. Michalek, and others have been involved in this project to accumulate as many attributes of the CMEs as possible along with related images and movies of solar activity from various sources. They are currently working on including one of the most important aspects of CMEs: the mass.

Magnetic Fields and Flows in the Distant Heliosphere. The Voyager 1 and 2 observations show that the global structure of the heliospheric magnetic field strength and solar wind direction continue to be described accurately by the spiral field model of Parker out to 87 AU (Burlaga et al., 2002a, 2003a). The Voyager 1 magnetic field data show that Voyager 1 did not cross the termination shock and enter a subsonic region during 2002 (Burlaga et al., 2003a). A Global Merged Interaction Region (GMIR) began to form at 15 AU and was fully developed at 60 AU. Small-scale fluctuations in B diminished with increasing distance from the Sun. The GMIR reached Voyager 1 and Voyager 2 in mid-2000, and it caused a major step-decrease in the cosmic ray intensity (Burlaga et al., 2003f). The corresponding radial evolution of the speed fluctuations from 1 to 60 AU was modeled by Burlaga et al. (2002c) and shown to be consistent with the Voyager 2 observations. A relationship between the speed and temperature outside AU at all latitudes was found by Whang and Burlaga (2003b), and this was used to predict that Voyager 1 is possibly within several AU of the termination shock (Whang and Burlaga, 2002d), which will soon be reced-

ing from the spacecraft. The radial evolution of solar ejecta was described and modeled by Richardson et al., 2002. The multiscale structure of the heliospheric magnetic field and solar wind speed was modeled by Burlaga et al. (2003b, e, f, g). The multifractal spectrum of the magnetic field observed by Voyager 1 near 40 AU was explained in terms of a deterministic MHD model by Burlaga et al. (2003d).

Complex Ejecta and Merged Interaction Regions at 1 AU. When successive CMEs are ejected earthward from the Sun, they can interact and merge to form flows called ‘complex ejecta’ which lose memory of the detailed structure of the original flows as the result of interactions. Burlaga et al. (2002b) showed that successive earthward directed halo CMEs were associated with complex ejecta at 1 AU. Burlaga et al. (2003h) showed that merged interaction regions can form between the Sun and 1 AU as the result of interactions among streams and that these MIRs can have important effects on geomagnetic activity and cosmic ray modulation.

7 SPACE SCIENCE MISSIONS AND MODELING: OPERATIONAL

7.1 VESPER

First Simulation Study on Venus Energetic Neutral Atom Emissions. Strong terrestrial Low Energy Neutral Atom (LENA) emissions were seen by the IMAGE LENA imager, coming from the subsolar magnetosheath during major magnetic storms. These enhancements are produced when high solar wind pressure pushes the magnetosheath into the outer geocoronal hydrogen population. Motivated by the terrestrial observations, M.-C. Fok has carried out the first ENA simulation on Venus, which has no intrinsic magnetic field and the solar wind directly interacts with its atmosphere, so high ENA emissions are expected. The calculation is based on a global Venus MHD model of Tanaka and colleagues. It is found that the simulated ENA emissions from Venus magnetosheath are comparable or greater than for the Earth. The Venus ionopause is clearly seen in the ENA oxygen images. This simulation work is done in support of the re-proposed Discovery mission: VESPER.

7.2 NEAR

Near Earth Asteroid Rendezvous (NEAR) Data Analysis Program. The NEAR X-ray/Gamma-Ray Spectrometer (XGRS) began orbital operations near 433 Eros in August 2000. The NEAR mission ended with the successful landing of the spacecraft on the surface of 433 Eros February 12, 2001. Members of the group consisted of a team leader, co-investigators and participating scientists for the NEAR XGRS. Significant results were obtained from the early analysis of the data. The results for both the elemental composition of the surface of Eros and the detection of gamma-ray bursts indicate: that Eros is broadly ‘primitive’ in its chemical composition and has not experienced global differentiation into a core, mantle and crust; and with the NEAR XGRS as

part of the Interplanetary Network, over 100 gamma-ray bursts were detected and for five of those detected, red shifts were determined. Under the NEAR data Analysis Program, a program for calculating the effects of particle size and distribution as a function of energy, incidence and emission angles has been undertaken. This information is needed for correcting the NEAR XRS data and will be of importance in interpreting the Messenger XRS data. We also hope to determine whether measurements at extreme angles can be used to infer something about surface particle size distribution. The efforts this year has been concentrated on developing the Monte Carlo methods available at the National Institute of Standards and Technology NIST for this calculation. Furthermore, advanced data analysis methods are being developed to: better analyze both the NEAR XRS and GRS spectra; and to better infer detail solar spectra from an interpretation of the proportional counter measurements.

7.3 Mars Odyssey GRS Program

J. I. Trombka and colleagues at the Astrochemistry group are involved as both Co-investigator and participating scientists on the Mars Odyssey Gamma-Ray and Neutron Spectrometer (MOGRNS). The MONS system started collecting data from Mars orbital January 2002 and the MOGRS orbital operation was initiated in April 2002. Statistically significant data is now available and analysis has been on going over this fiscal year to obtain abundance maps of a number of important elements including, for example H, K, Cl, Fe. Relative abundances have been obtained in some cases and detail studies are underway to obtain elemental concentrations. Some of the data has been presented at scientific meetings and a number of papers are in preparation detailing the results obtained.

7.4 CLUSTER II

The four Cluster spacecraft comprising this unique ESA/NASA Cluster mission continue to operate nominally. The main goal of Cluster is use four identically instrumented spacecraft to study small-scale three-dimensional plasma structures in key plasma regions such as the solar wind, bow shock, magnetopause, polar cusps, magnetotail and auroral zones. The orbital separation of the spacecraft is variable and a variety of separations have been employed since the mission was launched in the summer of 2000. Separations have ranged from close to 100 km to several thousand kilometers. Cluster’s payload comprises state-of-the-art plasma instrumentation to measure electric and magnetic fields from quasi-static up to high frequencies, and electron and ion distribution functions from energies of nearly 0 eV to a few MeV. The science operations are coordinated by the Joint Science Operations Centre, JSOC, at the Rutherford Appleton Laboratory (UK), and implemented by the European Space Operations Centre (ESOC), in Darmstadt, Germany. A network of eight national data centers, including the US node accessible via the CDAWeb inter-

face at the NSSDC at GSFC, has been set up for raw data processing, the production of physical parameters, and their distribution to end users all over the world. Data from 2001 from all the experiments is now available to the public from a variety of web sites: PEACE (A. Fazakerley, PI, Mullard Space Science Laboratory), WBD (D. Gurnett, PI, Univ. of Iowa), and WHISPER (P.M.E. Décréau, PI, Univ. Orléans, France) are accessible from <http://cluster2.space.swri.edu>. Data from CIS (H. Réme, PI, CESR, France) are available from http://cis.cesr.fr:8000/CIS_sw_home-en.htm. Data from EDI (J. Quinn, PI for NASA, Univ. New Hampshire) are available from <http://edi.sr.unh.edu>. EFW data (M. André, PI, SISP, Sweden) are available from <http://www.cluster.irfu.se/efw/data/spinfit/index.html>. Data from the RAPID experiment (P. Daley, PI, MPIA, Germany) can be found at http://leadbelly.lanl.gov/ccr/level2-data/cgi-bin/get_ccr_digital.cgi. Data from the STAFF experiment (N. Cornilleau-Wehrin, PI, CETP, France) is available from <http://www.cetp.ipl.fr/CLUSTER/accueil/framepa.html>. The Laboratory for Extraterrestrial Physics made significant contributions to several of the experiments, including, the PEACE, EFW, FGM. LEP provided the magnetometer sensors and analogue electronics. M. Acuña, D. Fairfield, and J. Slavin are the LEP magnetometer Co-investigators who participate actively in the data analysis effort. The NASA Project Scientist for Cluster is M. Goldstein.

Collaborative Studies Using Data from Cluster. Collaborative studies of isolated electrostatic structures observed in the auroral zone are underway using data from the Wide Band Data experiment (WBD) on Cluster, together with data from the Plasma Electron and Current Experiment (PEACE), Waves of High frequency Sounder for Probing of Electron density by Relaxation (WHISPER), and Flux Gate Magnetometer (FGM). M. Goldstein and D. Winningham (SwRI) are working with J. Pickett (Univ. of Iowa) on this research. Cluster PEACE, Cluster Ion Spectrometry (CIS), and Research with Adaptive Particle Imaging Detectors (RAPID) data are providing new insights into the structure and mass and energy flow through the polar cusp. W. Keith and M. Goldstein are participating in this project together with D. Winningham (SwRI), T. Fritz (Boston Univ.) and members of the CIS and WHISPER teams. Data from FGM (A. Balogh, PI, Imperial College) are providing new insights into the properties and dynamics of magnetic flux ropes in the near-earth plasma sheet. Data from the four Cluster spacecraft have been used to estimate the plasma current by computing the curl of the magnetic field. The analysis has revealed clear departures from the generally assumed force-free (i.e., $\mathbf{J} \times \mathbf{B} \sim 0$) condition within these structures. Utilization of the four spacecraft to time the passage of structures in the tail has allowed the first unambiguous separation of earthward from tailward moving traveling compression regions. M. Acuña, D. Fairfield and J. Slavin are the LEP magnetometer Co-investigators participating in the data analysis effort, along with M. Goldstein who is

providing electron data from PEACE.

Non-Gyrotropic Electron Distribution Functions and Wave-fields from CLUSTER/Peace and MAG Experiments. A study of non-gyrotropic electron distribution functions and wave-particle interaction has been initiated by A. F. Viñas, M. Goldstein, and C. Gurgiolo (Bitterroot Basic Research). Particle simulation results indicate that non-gyrotropic electron distributions can be generated by whistler waves very close to the Earth's bow shock. Such waves can be either shock driven or generated by anisotropic ion beams reflected at the shock. They are investigating various bow-shock crossings using all four Cluster spacecraft data sets for evidence of simultaneous wave activity and electron non-gyrotropic distributions.

Magnetic Fields Investigation. Cluster was launched and is now operational with 4 spacecraft flying in a controlled formation for the purposes of making coordinated magnetospheric particles and fields measurements. Central to achieving the scientific objectives of this mission is the magnetic fields investigation lead by Principal Investigator A. Balogh (Imperial College). The flight hardware for this investigation was designed and fabricated at several institutions with LEP providing the magnetometer sensors and analogue electronics. M. Acuña, D. Fairfield, and J. Slavin are the LEP magnetometer Co-investigators and they will participate actively in the data analysis effort. Initial investigations of magnetic flux ropes in the near-earth plasma sheet have used the curlometer technique to reveal clear departures from the generally assumed force-free (i.e., $\mathbf{J} \times \mathbf{B} \sim 0$) condition within these structures. Utilization of the 4 spacecraft to time the passage of structures in the tail has allowed the first unambiguous separation of earthward from tailward moving traveling compression regions. The NASA Project Scientist for Cluster is M. Goldstein.

Cluster Spacecraft Observations of the Dusk Flank Boundary Layer. Observations from three different experiments on each of 4 closely-spaced Cluster spacecraft are being used by D. Fairfield to study the boundary layer on the flank of the magnetosphere. The boundary layer is characterized by anisotropic field-aligned electrons with lower densities but slightly higher temperatures than those in the adjacent magnetosheath. Observed time delays of boundary crossings at spacecraft separations of 100's of km show the tailward propagation of Kelvin-Helmholtz waves.

7.5 IMP-8

Magnetic Field Investigation (MAG). The fall of 2003 marks the 30th anniversary of IMP 8's operation in orbit. The spacecraft has provided valuable solar wind, magnetosheath and magnetospheric fields and particles data over its long lifetime. The magnetometer (A. Szabo, Principal Investigator) has suffered an anomaly on June 10, 2000 preventing the collection of useful data. New attempts to reset the magnetometer and restore nominal operation have failed. The 15.36 seconds time resolution magnetic field data has been updated for the

whole duration of the mission at the publicly available CDAWeb. Also, the highest time resolution (320 msec) data set for the entire mission is currently reprocessed to facilitate faster and easier methods of public dissemination of this data. On-campus Co-investigators of this experiment are R. P. Lepping and J. Slavin and an off campus Co-investigator is N. Ness at the Bartol Research Institute, University of Delaware.

7.6 Polar

Polar was approved for an additional three-year mission extension for FY04 to FY06 as a result of the 2003 Senior Review. The extended mission will span the declining phase of the present solar activity cycle, a phase characterized by repeated encounters (hence long-lived) with high speed solar wind streams. Polar has not previously encountered the declining phase of a solar cycle. Polar's unique complement of instruments includes fully 3D electric and magnetic fields, complete in-situ velocity distributions of both electrons and ions from ~ 0 eV to 60 MeV, and detailed global multi-spectral imaging at visible and ultraviolet wavelengths. A new opportunity to reallocate telemetry will provide significantly higher resolution measurements of electric and magnetic fields in situ, while precession of the orbit's apogee through southern latitudes will provide new opportunities to study interhemispheric asymmetries of magnetospheric phenomena. The proposed science objectives were well received by the panel who found that the precession of the Polar orbit offers opportunities for conducting important scientific investigations of physical processes of interest to SEC. The panel recommended continued funding for the new science and the science support to be provided for the IMAGE and Cluster Missions. LEP scientists actively participating in the Polar Mission are Robert Hoffman (Polar Project Scientist Emeritus), Barbara Giles (Polar Project Scientist), Thomas Moore (Polar/TIDE Principal Investigator), Robert Pfaff (Polar/EFI Co-investigator), Donald Fairfield (Polar/Hydra Co-investigator), and Guan Le (Polar/MFE Co-investigator).

Thermal Ion Dynamics Experiment-Plasma Source Instrument (TIDE-PSI). (T. E. Moore, B. L. Giles) This year a breakthrough development occurred in which the evolving Polar orbit made possible observations of the low latitude dayside magnetopause region. As suggested by earlier observations at higher latitude [Chandler et al., 1999], and by recent results from the IMAGE mission EUV imager [Sandel et al., 2001], it was found that cold ionospheric plasma is abundantly present throughout this region, owing to the sunward convection of material from the outer plasmasphere and other flux tubes in the process of filling with outflowing ionospheric plasma. Depending on the depth of penetration of sunward flow, densities as high as 70 cm^{-3} have been observed just inside the magnetopause, in plasma that is clearly of ionospheric origin. Implications include a feedback effect on dayside reconnection, owing to mass loading by ionospheric plasmas in response to convection. A second

major effort this year has been to investigate the relationship between energy inputs to the ionosphere and plasma outflow rates in response. Inspired by a FAST study conducted by R. Strangeway, Y. Zheng has pursued this far enough to confirm that indeed, the best measures of ion outflow to be found in the conditions imposed by the magnetospheric solar wind interaction, include a) the Poynting flux of electromagnetic energy, and b) the density of precipitating electrons, which weights strongly the lowest energy electrons (in the range 15 eV to 15 keV). Publication activity in 2003 has focused on the former of these two studies, while the latter is expected to be published in the coming year.

7.7 Wind

WIND/SWE VEIS-Strahl Analysis. A. F.-Viñas, K. W. Ogilvie, and M. Holland (GSFC/587) have implemented a new analysis tool for the data collected by the Strahl instrument onboard the WIND spacecraft to obtain measurements of the electron density and temperature in the solar wind since the SWE/VEIS instrument have ceased functioning last year. The results are consistent with similar measurements onboard the ACE spacecraft.

Wind Magnetic Field Investigation (MFI) Health and Status. The WIND MFI magnetometer system continues to function nominally. The mission data set is made publicly available as rapidly as possible. This includes 1-hour averages, 1-min averages, and higher time resolution (3 sec) data from the team's web site, the ISTP CDAWeb, or directly from the MFI team. In addition, added value support data, such as bow shock crossing times, list of magnetic clouds and interplanetary shocks are constantly updated on the team's web site. The very highest (msec) time resolution data continues to be distributed on an individual request basis. Some of the team's research areas are studies of the properties of the interplanetary medium, their comparisons to solar events, the magnetosphere's boundaries, and magnetotail events especially during active periods. MFI's website also contains a bibliography of about 205 WIND articles and papers on which a team member is either author or co-author. The Laboratories' members on the MFI team are M. Acuña, L. Burlaga, M. Collier, W. Farrell, R. Lepping (Principal Investigator), J. Scheifele, J. Slavin, A. Szabo (Data Production Manager), and E. Worley, as well as three off-Center members.

7.8 Geotail

The Geotail spacecraft remained in good health during its eleventh year of operation and it continues to provide excellent data from its 9×30 Re equatorial orbit. Long Earth shadows are the primary hazard to Geotail's health and this spacecraft has survived the longest shadows that it will encounter. Much of the Geotail data is now available via the web, including CPI plasma data from the solar wind detector and LEP plasma data from both the solar wind and energetic plasma detector. The latter data, along with the MGF magnetic field data, is

available via the Japanese DARTS system and will soon be available from the National Space Science Data Center. Severe budget constraints have reduced the Geotail budget to the extent that it only provides enough money to U.S. Principal Investigators to reduce their data to scientifically usable parameters. Despite this limitation, Geotail continues to make important contributions to the Sun-Earth Connections program since many outside investigators use the data to study processes such as the entry and redistribution of energy and particles in the magnetosphere. Geotail spends roughly half its time in the solar wind, and with the WIND spacecraft spending most of its time far from Earth, Geotail is the only spacecraft providing near-Earth measurements of the interplanetary magnetic field. D. Fairfield is NASA's Geotail Project Scientist.

7.9 IMAGE

Imager for Magnetopause to Aurora Global Exploration (IMAGE). (T. E. Moore, M.-C. Fok) The IMAGE mission progressed from qualitative discoveries into quantitative measurements and testing of theories during 2003. Areas of recent activity include: the finding that an asymmetric feature of the Comprehensive Ring Current Model (CRCM) is actually observed during major storms; that the plasma sheet density responds to solar wind variations; that the high latitude dayside proton auroral spot indeed maps to a high latitude reconnection region; that ionospheric neutral atom emission to high altitudes originates from a region at $\sim 1 R_E$ altitude; that plasmaspheric drainage plumes are observed as ionospheric density features and as density enhancements at the dayside magnetopause; and that there are multiple data sets showing evidence of a secondary stream in the interstellar neutral atom flow. IMAGE was rated 4th of 14 operating missions by the senior review of operating missions, and was designated for an extended mission into FY04-07 (albeit at a funding level slightly lower than what was considered sufficient for "bare-bones" operations by the science team). The IMAGE spacecraft and all instruments continue to perform outstandingly well into the fourth year of operations, supporting a high rate of science results publication (see Web-site <http://image.gsfc.nasa.gov/publication/>). The invited papers from a workshop on IMAGE early results held in Feb 2002 will reach printing in Space Science Revs. in 2003.

Low Energy Neutral Atom Imager (LENA). (T. E. Moore, M. R. Collier, M.-C. Fok) LENA science investigations during 2003 have included: a simulation study of LENA emission expected from Venus, based on IMAGE experience; a study of the dayside magnetosheath and cusp regions using neutral atom emissions; a detailed correlation study showing that ionospheric neutral atom emission seen in close correlation with solar wind variations, originates from a region at $\sim 1 R_E$ altitude; a study showing that diverse data sets point toward a secondary stream of interstellar neutral atoms flowing through the solar system; a study inferring the inner solar system

dust column density to be near the high end of a broad range of prior observations. LENA imager operations have been restored after a period in 2002 when it was thought that the neutral-ion conversion surface had lost effectiveness in space. However, it was determined that detector gain loss was the culprit and this was easily corrected with high voltage bias adjustments. The LENA conversion surface appears to be continually refreshed by perigee passes through the exosphere at ~ 1000 km altitude.

Magnetospheric Radio Sounding. R. F. Benson, J. Fainberg and V. Osherovich at GSFC continue the interpretation of plasma resonances stimulated by the Radio Plasma Imager (RPI) on the IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) satellite. Working with RPI PI B. W. Reinisch and colleagues at the Univ. of Mass., Lowell, and with other members of the IMAGE/RPI team, these resonances are used in the determination of magnetospheric electron-density profiles and the *in situ* electron density and magnetic-field strength along the IMAGE orbit. P. Webb, during his final year as a NASA NAS/NRC Resident Research Associate, modified his dynamic global model of the plasmasphere so as to be more suitable for comparisons with the IMAGE data, developed an automatic fitting routine to locate the peak of the upper-hybrid emission band in the passive RPI dynamic spectra, and participated in the comparison of active and passive determinations of the electron density from the IMAGE/RPI data.

Ring Current Plasmasphere Modeling in Support of the IMAGE mission. Energetic ion fluxes and the associated energetic neutral atom (ENA) images have been simulated by M.-C. Fok during active periods since the launch of the IMAGE mission. The tool of the simulations is the Comprehensive Ring Current Model (CRCM), which combines Fok's ring current model and the Rice Convection Model. The CRCM calculates ring current ion distributions as well as the subauroral potentials that are consistent with the distributions of the hot ions. Recently, a plasmasphere model of Ober (Mission Research Corporation) and Gallagher (MSFC) was embedded in the CRCM to study the storm time development of the plasmasphere. IMAGE EUV observed an "undulation" of the duskside plasmasphere on 17 April 2002. A post-dusk indentation formed in a pre-existing plume, and then propagated sunward along the dusk edge of the plume. During the time that EUV saw the dusk side plasmopause undulation, DMSP flow data showed a strong (~ 1 km/sec) westward flow on the duskside, known as the Sub-Auroral Polarization Streams (SAPS), so the plasmasphere undulation is plausibly due to SAPS flow enhancement near dusk. The CRCM-plasmasphere simulation reproduced both the timing and the structure of the plasmasphere undulation on 17 April 2002. The ionospheric drifts calculated from the CRCM potentials also showed a SAPS signature when there is plasmasphere undulation, supporting the argument that this undulation is the result of the fast SAPS flow. All these simulation results are posted at

7.10 CASSINI

Cassini Plasma Spectrometer (CAPS). E. Sittler is a Co-investigator for the CAPS (Cassini Plasma Spectrometer) instrument. CAPS is composed of five major subsystems. They are the Ion Mass Spectrometer (IMS), Electron Spectrometer (ELS), Ion Beam Spectrometer (IBS), Data Processing Unit (DPU) and Actuator (ACT). As Co-Investigator for CAPS, E. Sittler has been in charge of flight software development for the CPU2 and Spectrum Analyzer Module (SAM) boards which are subunits of the DPU and the scientific analysis of CAPS data at GSFC. SAM accumulates TOF data from the IMS to form TOF spectra and then deconvolves this spectral data to compute ion counts for various ion species. CPU2 is dedicated to acquiring data from the IMS and make IMS data products, which are then transmitted to the ground. Recently, we have made major revisions to the data products made by CPU2 in order to maximize scientific return within telemetry constraints. The Cassini spacecraft is rapidly approaching the Saturn system with orbit insertion on July 1, 2004. The CAPS instrument has operated nominally during this whole period. The primary composition of the solar wind during the cruise phase has been observed to be protons and alpha particles over a wide range of energies. We are in the process of analyzing the cruise data for interstellar pickup ions and the recent submittal of a paper by McComas et al. (2003). This analysis includes observation of the pitch angle distributions of the interstellar ions and their relationship with magnetometer observations in the solar wind. We are in the process of performing a major effort with regard to the calibration of the prototype unit and then cross-calibrating this data to the limited calibration data for the flight unit. In addition to this we are constructing a Monte Carlo calculation of the IMS, which takes into account the randomness of events entering the spectrometer. This code will eventually allow us to understand the calibration data acquired from the IMS.

Cassini Planetary and Cometary Physics. E. Sittler, as CAPS Co-investigator, has performed a simulation of pickup ion observations at Dione and Enceladus that would be observed by CAPS during flybys of these icy satellites. These results will appear in JGR (Space) (Sittler et al., 2003). The model includes a sputtered atmosphere for each icy satellite and ion production is produced by photoionization, charge exchange and electron impact ionization. The atmosphere is assumed to be optically thin and finite gyro-radii effects are shown to be small. As a fluid element passes through the atmosphere ions are accumulated by the ionization mechanisms noted above to yield a pickup ion density at the assumed observation point where the Cassini spacecraft is located. This information is then used to produce simulated data products that would be produced during the separate icy satellite encounters. These data products are in the form of ion distribution functions

and energy-TOF spectrograms. The pickup ions are assumed to form ring distributions, which can readily be distinguished from ambient ions. The observed ion abundances of pickup ions can be used to determine the composition of the icy satellite surfaces.

E. Sittler and collaborators are presently preparing a paper for publication on energetic nitrogen ions within Saturn's inner magnetosphere. Here, exothermic reactions within Titan's upper exosphere will produce a giant nitrogen torus encircling Saturn and centered on Titan's orbital position, which will then be ionized forming a hot keV plasma of nitrogen ions within Saturn's outer magnetosphere. This plasma of hot nitrogen ions will be competition with hot protons from the solar wind. This hot plasma will then radially diffuse into Saturn's inner magnetosphere forming an energetic population of nitrogen ions within Saturn's inner magnetosphere. Loss mechanisms such as satellite sweeping, pitch angle scattering and rotational electric fields will tend to enrich the presence of nitrogen ions relative to protons within Saturn's magnetosphere. They then consider the kinds of chemistry that may be driven within the ice of the icy satellites from energetic nitrogen bombardment. Previously, the energetic heavy ions within Saturn's inner magnetosphere was thought to be oxygen.

They have also uncovered an unpublished technical memorandum by Lepping et al. (1986) on MHD waves observed by Voyager in the outer magnetosphere of Saturn. E. Sittler is leading the effort to get this manuscript published to lay the ground work for MHD wave observations within Saturn's magnetosphere by Cassini. These results are also being used by Sittler et al. for the energetic nitrogen paper.

Cassini Composite InfraRed Spectrometer (CIRS). The primary activity of the CIRS team (personnel at GSFC are F. M. Flasar (Principal Investigator), R. K. Achterberg, G. L. Bjoraker, J. C. Brasunas, D. E. Jennings, V. G. Kunde, C. A. Nixon, J. C. Pearl, P. N. Romani, R. E. Samuelson, M. E. Segura, and A. A. Simon-Miller) has been planning and sequencing the observations for the Saturn tour, with the Cassini spacecraft orbital insertion set for July 1, 2004. CIRS will make a key set of observations of Titan shortly after the insertion, to measure spatial variations in atmospheric temperature. This information will be used in last-minute planning of the descent of the Huygens probe onto Titan, which is planned later in the year in December. CIRS observations of Jupiter in November 2000-February 2001, during the Cassini swingby, have identified an intense equatorial jet, previously unidentified. Several trains of thermal features have been seen in Jupiter's stratosphere with a westward drift, suggesting Rossby-wave propagation. Observations at high spectral and spatial resolution have mapped two molecules believed to have been injected into the atmosphere by the Shoemaker-Levy 9 impact in 1994: HCN and CO₂. The distribution of the former is simply explained by lateral spreading from the impact sites near 45° S. However, the maximum abundance of CO₂ has been displaced southward toward the

pole. The apparent disparity between these two results is puzzling, and interpretive studies are underway. The CIRS Jupiter observations have also identified for the first time the methyl radical, a key intermediate product in the dissociation of methane.

J. Brasunas and B. Lakew performed a study of the long-term stability in space of the CIRS FP1 infrared detectors on the CASSINI mission. An observed decline of only 1/2% over a two-year period bodes well for instrument performance during the main phase at Saturn, beginning in July of 2004.

7.11 Ulysses

As of October 2003, the Ulysses spacecraft was nearing aphelion (at a distance of more than 5 AU from the Sun) and a heliographic latitude of approximately 0° . As the Sun draws closer to solar minimum, the level of solar radio burst activity is greatly reduced. The Ulysses trajectory is carrying the spacecraft closer to Jupiter (currently 1.2 AU) and a variety of Jovian radio emissions are detected routinely; permitting correlative studies with Cassini. Ulysses will approach to within about 0.8 AU of the planet, permitting extensive radio studies to be undertaken. Due to its highly inclined orbit, the spacecraft will reach a jovigraphic latitude of 75° , providing a unique perspective of Jovian radio emissions, which are highly latitude dependent. These observations will be correlated with other space-based (Chandra, HST) and ground-based observations of Jovian auroral zones.

The GSFC contributions to Ulysses include involvement with two of its instruments: the Unified Radio and Plasma Wave investigation (URAP) and the Solar Wind Ion Composition Spectrometer (SWICS). URAP Co-investigators at GSFC are M. Desch, J. Fainberg, M. Goldstein, M. Kaiser, R. MacDowall (Principal Investigator), M. Reiner, and R. Stone (PI Emeritus); K. Ogilvie is an unfunded Co-investigator on the SWICS team. The research activities of these groups are detailed above.

7.12 Voyagers 1 & 2

Voyager 1 and 2 Magnetometers. The magnetometers on Voyagers 1 and 2 continue to function as designed and return data from explored regions of the distant heliosphere. They are now approaching the termination shock and heliosheath. Voyager 1 is now near 90 AU at a latitude of 35° N, and Voyager 2 is beyond 70 AU at a latitude of 28° S. L. Burlaga is responsible for the reduction of the data and is active in the analysis of these data.

7.13 Fast Auroral Snapshot Explorer (FAST)

NASA's FAST satellite continues to acquire excellent data and provides an exciting new look on acceleration processes at the interface of the hot, magnetospheric plasma and the cool, ionospheric plasma in the earth's high latitude region. The FAST science team has already reported several major discoveries, such as the prevalence of upwards electron beams, ion conics and

beams, solitary structures, auroral kilometric radiation, and the role of Alfvén waves in the auroral process. Instruments on FAST include fast energetic electron and ion spectrometers, vector DC and AC electric and magnetic field detectors, and an energetic ion composition instrument. The Principal Investigator for FAST is C. W. Carlson of the Univ. of California, Berkeley. R. Pfaff is the NASA Project Scientist for the FAST mission.

7.14 Communications/Navigation Outage Forecast System (C/NOFS)

Goddard's Vector Electric Field Investigation (VEFI) has been built, tested, and provided to the Air Force C/NOFS satellite to be launched in late 2003. The main objective of the satellite is to study irregularities in the equatorial ionosphere that disrupt communications and navigation systems. Such irregularities are generally associated with equatorial "Spread-F" and are linked to ionospheric plasma depletions and variable DC and AC electric fields. The planned orbit of the C/NOFS satellite is 400 by 700 km with a 13 degree inclination. The VEFI experiment includes instrumentation to measure DC and AC electric fields, and includes a burst memory, on-board signal processing, and a filter bank. In addition, the VEFI experiment includes a magnetometer sensor provided by M. Acuña (GSFC), a lightning detector (design and testing provided by the Univ. of Washington), and a fixed-bias Langmuir probe (GSFC) which serves as the trigger input for the burst memory. R. Pfaff is the Principal Investigator of the VEFI instrument for C/NOFS. He is also the NASA Project Scientist for C/NOFS.

8 COMMUNITY COORDINATED MODELING CENTER (CCMC)

The CCMC is an inter-agency activity aiming at research in support of the generation of advanced space weather models. CCMC's central facility is located within the Laboratory of Extraterrestrial Physics with GSFC. New and improved space research models will be created by combining models and modules. Models and modules will be developed mostly in the scientific community, but also at the CCMC GSFC facility itself if required. The ultimate goal of the CCMC is the generation of a flexible chain of comprehensive space weather models, which cover the entire range from the solar corona to the Earth's upper atmosphere. Combined models will have switchable modules, covering different regions and different physics. Models, which have been developed and passed metrics-based evaluations and science-based validations will be handed off to the Rapid Prototyping Centers of NOAA and the Air Force, for operational testing. These models are also available to the scientific community for runs-on-request, to support the "open model policy."

During the past year, the CCMC has greatly expanded the number of resident models. At the present time, models accepted and implemented at the CCMC include two magnetospheric global MHD models, one

ring current/radiation belt model, which has been successfully coupled to the MHD models, two physics-based ionospheric models, one empirical ionospheric electric field and current model, a solar coronal MHD model, and an interplanetary structure model, which is based on interplanetary scintillation measurements. Of these, all but the latter two are available for runs requested by the research community. This feature is being heavily used, with in excess of 140 requests executed to-date. Runs-on-request are executed through an automated, standardized, and easy-to-use interface, developed at CCMC, and subjected to postprocessing, with minimal human involvement. Access to run results is provided through a continually improved web-based idl interface, which permits display of all relevant physical quantities in arbitrary planes and along arbitrary lines. CCMC's experimental real time system has been expanded to include a ring current model, driven off a global MHD model.

For the purpose of maintaining close communications with both science and operational communities, CCMC established two advisory committees. The first, science committee advises the CCMC steering committee on the scientific value of candidate models, and recommends models for inclusion into the CCMC process. The second, operations committee, evaluates the space weather potential of candidate models.

CCMC performs the first comprehensive and repeatable metric-based analyses of space science models. CCMC successfully transferred an update of the Michigan MHD model to the Air Force rapid prototyping center (RPC). In addition, the Weimer Polar Cap model has been sent to both Air Force and NOAA RPCs, after completion of the metrics-based evaluation. The ring current model has been transferred to the Air Force RPC in early August.

Ring Current Model Run in Real Time at CCMC. M.-C. Fok, together with staff in the CCMC have successfully established the real-time running of the Fok's ring current model inside the batsrus MHD model. The ring current model takes magnetic field, electric field, plasmas sheet temperature and density output from the MHD model and calculates the spatial, energy and pitch-angle distributions of ring current fluxes. The result of this real-time running can be found at <http://ccmc.gsfc.nasa.gov>. The ongoing effort is to modify and extend the batsrus-Fok model to radiation-belt energy so that the combined model will provide now-casting of the radiation-belt environment.

9 INSTRUMENT DEVELOPMENT

New-Concept in Mass Spectrometer Development. J. Keller with M. Coplan (Univ. of Maryland), O. Vaisberg (Space Research Institute) and N. Dionne (Raytheon) are developing a new-concept mass spectrometer suitable for helio- and magnetospheric composition studies. Their method introduces a fundamental improvement in the innate resolving power of the mass spectrometer while maintaining characteristics, such as low mass and power that are desirable for space plasma measurements.

They introduce multipath time-of-flight mass analysis for spacecraft instrumentation in a compact miniaturizable geometry. A small magnetic field inside a spherical analyzer induces precession in the orbits eliminate the lapping of slower ions by faster which otherwise make the identification of ions difficult.

High Tc transition-edge Superconducting (TES)

Bolometers Development. B. Lakew, J. C. Brasunas, S. Aslam (GSFC), R. Boyle (GSFC) together with R. Fetting (IMT -Germany) organized a highly successful International Workshop on Thermal Detectors for Planetary Applications- TDW03- (June 19-20, 2003) in College Park, MD. Many papers were presented by LEP scientists and collaborators. Participants came from the U.S., Canada, Europe and Asia.

B. Lakew, and co-workers developed a far infrared TES bolometer on a monolithic sapphire membrane as a substrate. Results were submitted for publication. Work is continuing with B. Pugel (GSFC) to optimize architecturing of sapphire substrate. B. Lakew is PI on this effort partly funded by NASA's technology development program. Use of silicon-on-insulator (SOI) as substrate material for TES bolometers is also being investigated by the team.

Planetary Bolometers and Spectrometers. J. Brasunas, in concert with B. Lakew, R. Fetting, S. Aslam, and D. Pugel, has continued the development of moderately cooled infrared bolometers based on thin-films of the high temperature superconductor (HTS) materials YBCO and GdBCO. In support of future space missions, a single-stage Stirling cycle cooler has been procured and brought on line, to gain familiarity with temperature stabilization and vibration issues.

HIPWAC Instrument Development. The new Heterodyne Instrument for Planetary Wind And Composition (HIPWAC) has now been used on six observing runs at the NASA Infrared Telescope Facility (IRTF) in December 2000, February 2001, August 2001, August 2002, January 2003, and June 2003. HIPWAC is an advanced infrared heterodyne spectrometer (IRHS) for the measurement of molecular lineshapes and the wind-driven Doppler shifts of molecular lines formed in low-pressure, high altitude, regions of planetary atmospheres. Present HIPWAC development activities include upgrading the optics, expanding remote control capabilities, upgrading the calibration and stabilization systems, improving the back-end electronics, and refitting the instrument for operation on the Subaru 8m telescope facility. The HIPWAC team is led by T. Kostiuk and includes GSFC personnel J. Annen, D. Buhl and K. E. Fast, NRC Associate G. Sonnabend, as well as T. A. Livengood and J. J. Goldstein, and T. Hewagama. Design support and CAD drafting has been provided by P. Rozmarynowski and F. Hunsaker. Mechanical engineering and composite-materials fabrication of the HIPWAC optical benches, optical mounts, and laser cavities was provided by K. Segal and P. Blake of the Mechanical Engineering Branch (GSFC, Code 543). Research Assistant J. Delgado (UMD) characterized optical compo-

nents and subsystems in the laboratory and was able to attend and significantly contribute to the third HIPWAC instrument-commissioning run on the IRTF.

Improved performance of HIPWAC derives from implementation of new technologies and from the characteristics of large (8-10m) telescopes accessible to a transportable instrument: (1) factor of ~ 10 improvement in sensitivity on small targets compared to a 3m telescope; (2) improved spatial discrimination; (3) reduced velocity broadening due to the range of Doppler shift from planetary rotation across the diffraction-limited FOV; (4) improved system quantum efficiency compared to current components; (5) flexible access to available telescopes; and (6) access to different latitudes from which to observe. The prototype 1 meter-length cavity for the CO₂ laser local oscillator was used in the December 2000 and February 2001 runs. The advanced dual-laser-tube cavity supporting 0.5m tubes was used from August 2001 onward. The IRHS group presently is investigating the replacement of aging discrete RF filter technology using a modern acousto-optic spectrometer system for signal processing. Work is continuing on an overall upgrade to mate HIPWAC to any of the general class of 8-10m telescopes now in operation and to improve data acquisition software.

Ion Composition Plasma Spectrometer. As Principal Investigator of a SECID NRA, E. Sittler is developing an advanced version of a 3D Ion Composition Plasma Spectrometer that uses time-of-flight (TOF) technology and solid state detection for a triple coincidence detection capability and the ability to measure the ions mass and charge state. The design is an improvement of that used for CAPS with an essential elimination of background events and enhance detection capability which further reduces accidental coincidences. This allows one to reduce spectrometer size by a factor of 3 with better performance and sensitivity to that provided by CAPS. This effort is being done in collaboration with the University of Maryland College Park, the Applied Physics Laboratory (APL) and the Los Alamos National Laboratory. They are also working on a novel laser cooling technology that will allow one to cool the SSD and FET to -60 C and thus reduce detector and electronics noise. This will allow one to use only -15 kV post-acceleration instead of -25 kV, thus reducing instrument risk. The energy range is 1 V to 50 kV. They are also developing a time delay anode for the micro-channel plates for position detection and using the TOF chips developed by APL. The APL TOF chips are also used for the TOF measurements. This technology will allow them to build a very compact design for the ion composition plasma spectrometer. This is a 3 year effort and the progress is presently on schedule.

Miniaturized Plasmas Analyzers (IR \mathcal{E} D). T. Moore, M. R. Collier, and J. Lobell have been developing miniaturized analyzers for plasmas, appropriate to multi-spacecraft missions such as the Magnetospheric Multi-Scale Mission (MMM) and Magnetospheric Constellation Mission (MCM). In the second year of this effort,

attention has been focused on the electronics instead of the particle optics. Additional progress was made in the fabrication of miniature high voltage supplies with lightweight transformer coils designed as an integral part of a multilayer board. The miniaturized high voltage power supply is being developed in coordination with these instrument concepts by A. Ruitberg (GSFC). The greatest effort this year, however, went into the design and fabrication of an ASIC implementation of a detector pulse accumulator. The ASIC solution for sweep coordination and data acquisition is being developed, in collaboration with M. A. Johnson and other GSFC/Code 500 personnel. Lab vacuum testing of the HV supplies and ASIC prototype is about to begin in late FY03.

Nanotechnology. E. Sittler is a member of the Nanotechnology Working Group at GSFC. He is working with the engineering directorate with regard to the application of nanotechnology to future scientific instrument concepts for future NASA missions. He is presently working on a roadmap for reducing the resource requirements of future instrument concepts while enhancing instrument performance and sensitivity. He is also working on novel radiation shielding strategies such a magnetic shielding of electronics from MeV electrons. This technology involves filling carbon nanotubes (CNT) with a high μ material, putting these CNT's into a polymer substrate such that they are all co-aligned and then laminating many sheets together. One could then take these sheets to Sandia National Laboratory high field facility and magnetize them where the field is confined within the polymer. One can then wrap the shielding material around the electronics. An MeV electron would have a gyro-radius within these sheets of only 0.2 mm and be deflected by the magnetic field from entering the electronics box. They are also looking into wireless technologies such that micro-chips can communicate with each other at very high bit rates and eliminate the need for circuit boards. This is just a sample of the technologies being considered.

E. Sittler also presented a paper at the International Thermal Detectors Workshop in June 19-20, 2003, on upcoming and future missions in the area of infrared astronomy. This talk covered astrophysics, planetary science, Earth science, solar physics and ground based telescopic observations. The conference paper is presently in the review cycle.

10 SOUNDING ROCKETS AND SUB-ORBITAL PROGRAMS

Program Status. NASA's Sounding Rocket Program provides a cost effective, rapid means to carry out unique scientific experiments in space, as well as to test new flight instrumentation. Sounding rockets provide the only spaced-based platforms with which scientists can carry out direct in-situ measurements of the mesosphere and lower ionosphere/thermosphere (40-120 km), regions which are too low to be sampled directly by satellite-borne probes. Furthermore, they provide access to high altitudes where astronomy, planetary, and

solar observations can be gathered of radiation at wavelengths absorbed by the Earth's lower atmosphere, including emissions from objects close to the Sun (e.g., comets, Venus, Mercury), which are precluded from observations by other spaced based observatories such as the Hubble Space Telescope. Sounding rocket platforms are ideal for a variety of microgravity experiments as they have a very low "g-jitter" environment, particularly compared to human-tendered platforms such as the Space Shuttle and International Space Station. Other unique features of sounding rockets include their ability to gather data along vertical trajectories, their low vehicle speeds (compared to satellites) with long dwell times at apogee, the fact that they may be launched into geophysical "targets" (e.g., thunderstorms, aurora, cusp, equatorial electrojet, etc.) when conditions are optimum including operations at remote launch sites, the recovery and re-flight of instruments and payloads, and the acceptance of a greater degree of risk which helps maintain the low cost aspect of the program. Sounding rockets also provide invaluable tools for education and training. Over 350 Ph.D.'s have been awarded to date as part of NASA's sounding rocket program. Missions are selected each year based on peer-reviewed proposals selected by various science discipline offices at NASA Headquarters. R. Pfaff is the Project Scientist for NASA's Sounding Rocket Program.

High Altitude Rocket Experiments in the Dark Cusp from Spitzbergen, Norway. On December 14, 2002, NASA launched a successful sounding rocket from Spitzbergen, Norway into the dayside cusp during darkness. An important set of simultaneous ground-based and satellite data are also available. The rocket was flown during Bz South conditions and returned DC electric and magnetic fields, plasma waves, energetic particles, and thermal and suprathermal plasma data. The overall investigation was led by R. Pfaff, who also provided the electric field and Langmuir probe hardware. Goddard's continuing effort concerns the analysis of the measurements of electrodynamic parameters on the payload that were gathered with instruments built at the NASA/GSFC. M. Acuña (GSFC) provided the magnetometer sensor.

Dual Rocket Experiments to study Joule Heating in the High Latitude, Lower Ionosphere. Two instrumented rockets were launched into a post midnight phase of a sub-storm from Poker Flat, Alaska on March 27, 2003, that contained DC and wave electric fields and thermal plasma instruments built in GSFC/LEP. This research involves quantifying Joule heating contributions from both DC electric fields and electric field fluctuations at altitudes where the Pedersen conductivity (and hence the heating effects) maximize. The rockets achieved apogees of ~ 200 km and revealed highly structured electric fields along their trajectories. Neutral wind measurements were gathered using a TMA trail from a third rocket. These combined data will enable direct measurements of Joule heating in the auroral E-region for the first time. These rockets also encountered intense

two-stream waves in the auroral electrojet on their up-legs which will be analyzed in terms of Farley-Buneman two-stream flows and turbulence.

Gravity Waves. R. Goldberg led an international scientific team in the winter MaCWAVE Rocket Program, launched at ESRANGE (Sweden) during January 2003 to study gravity wave effects on the polar winter mesosphere. Two sequences, each involving a Terrier-Orion payload and several MET Falling sphere flights were launched on January 24 and 28. These were accompanied by rawinsonde balloon flights at both ESRANGE and Andøya Rocket Range (ARR). ESRANGE and ALOMAR (at ARR) lidars and radars provided continuous ground-based sounding support during each sequence. The winter program was planned to study the upward propagation and penetration of mountain waves from northern Norway into the MLT at a site favored for such penetration, viz. downstream (east) of the mountains at ESRANGE. However, a polar stratospheric warming just prior to the rocket window induced stratospheric wind shears, which prevented mountain wave penetration into the mesosphere. Instead, the observed wave structure in the mesosphere originated from other sources. The data from these measurements are expected to permit tracking of the waves from their tropospheric origin into the mesosphere, determine if the waves break there, and evaluate the energy dissipation produced by such breaking. The first phase of this two part program, was launched from ARR during polar summer (July, 2002). The summer gravity waves were generated by convective disturbances such as frontal systems and electrical storms in the troposphere. Analysis and interpretation of the data is now in progress. The MET rocket data have also been used for validation studies with data from the SABER instrument aboard the NASA TIMED satellite. Presentations have been made at several national and international conferences. In addition, a special section for GRL is now under preparation.

ALTUS Uninhabited Aeronautical Vehicle (UAV). M. Desch, W. Farrell, R. Goldberg, and J. Houser were part of a team selected to conduct flights on the ALTUS UAV during Summer 2002. The flights occurred from the Naval Air Station in Key West, Florida. This was a team effort with MSFC, R. Blakeslee, Principal Investigator. The payload was designed to measure the electromagnetic energy generated in the upward direction above thunderstorms. During August 2002, the UAV accumulated over 40 hours of flying time above 40K feet, with numerous passes over active electrical storms. The data is now under analysis. Preliminary results have been presented at several national and international conferences.

11 FUTURE MISSIONS

11.1 Living with a Star (LWS) Program

The goal of the Living with a Star Program (LWS) is to develop the scientific understanding necessary to effectively address those aspects of the connected Sun-Earth

system that affect life and society. As presently envisioned, LWS has solar, heliospheric, magnetospheric and ionospheric elements, but emphasizes a unified systems-based approach to space weather. The program has as a central element a strong theory, modeling and data analysis and assimilation aspect. Furthermore, there is a robust technology development and flight test program to provide new instrumentation. Under the direction of the SEC Theme Director a LWS Management Operations Working Group (MOWG) was assembled in 2003 to support the LWS Project Scientist at NASA HQ. LEP scientists actively participating in the LWS effort are A. Szabo (Solar Sentinels Project Scientist), R. Hoffman (Geospace Study Scientist), B. Giles (Geospace Project Scientist), J. Grebowsky (Geospace Deputy Project Scientist), M. Hesse (Theory and Modeling Project Scientist), A. Roberts (Data Systems), R. Vondrak (Steering Committee), J. Slavin (Steering Committee), and D. Sibeck (LWS detailee to NASA HQ to serve as Deputy Project Scientist for the LWS program and to manage the Targeted Research and Technology program and addressing issues related to the Geospace elements of the program).

Sentinels. The goal of the LWS Sentinel element is to gain an understanding of the fundamental physics that connects solar phenomena to geoeffective events. The Heliospheric Strategy panel is completing a white paper addressing the scientific objectives and available opportunities for this program element. With the leadership of NASA Headquarters, a successful international cooperation has been initiated to maximize the scientific returns of all currently planned international missions in the heliosphere. The U.S. mission components of Sentinels are expected to be launched no earlier than 2009. A. Szabo is the Sentinels Project Scientist.

LWS Geospace Missions. A Geospace Missions Definition Team (GMDT), composed of scientists knowledgeable on the subjects of the radiation belts, the ionosphere-thermosphere system, and Space Weather Program needs completed their effort. Their report recommended a set of science investigations that emphasize understanding *and* characterization of the targeted regions of geospace. Specifically, the Geospace Project's highest priority objectives are to:

1. Understand the acceleration, global distribution, and variability of energetic electrons and ions in the inner magnetosphere;
2. Determine the effects of long- and short-term variability of the Sun on the global-scale behavior of the ionospheric electron density;
3. Determine the solar and geospace causes of small-scale ionospheric density irregularities in the 100 to 1000 km altitude range; and
4. Determine the effects of solar and geospace variability on the atmosphere enabling an improved specification of the neutral density in the thermosphere.

The GMDT recommended flight elements are contained in two coupled investigations, a Radiation Belt Investigation and an Ionosphere-Thermosphere Investigation. The Radiation Belt Investigation consists of three

spacecraft: two Storm Probe satellites in low inclination elliptical orbits, and an energetic neutral atom imager on a third spacecraft in a high-latitude, high altitude orbit. The Ionosphere-Thermosphere Investigation consists of two identical Storm Probe spacecraft in circular, 60° inclination low-Earth orbits with ascending nodes separated by 10° to 20° in longitude, and a mid-latitude far ultraviolet (FUV) imager in geosynchronous orbit on a mission of opportunity. The Geospace Project Office has been studying the recommended mission elements and moving forward with implementation of a core set affordable within program cost caps. For full program implementation, NASA will need to rely on a number of other U.S. and international programs, both to provide flight opportunities and also to fill gaps in understanding and specification ranges by providing simultaneous and complementary data.

Participation in LWS has been supported through a variety of opportunities. NASA Research Announcements targeted to LWS objectives are offered each year. There was an open workshop held in mid-November 2002 and a "Town Hall" meeting at the fall 2002 AGU convention to present the GMDT report and welcome feedback from the scientific community. An Announcement of Opportunity for science investigations for the ionosphere-thermosphere flight initiative is expected in the coming year with another for the radiation belt flight initiative following at a later date. Contingent upon receiving final budget approval, the LWS Geospace project office will be expanded in the coming year and further implementation undertaken.

Visual System for Browsing, Analysis, and Retrieval of Data (ViSBARD), a Precursor to a Space Physics Virtual Observatory (SPVO). D. A. Roberts, in collaboration with commercial software developers and other GSFC personnel (including M. L. Goldstein, T. E. Moore) have produced a new way of visualizing data that makes it possible to view simultaneously a large number of measured time series on the orbits of a large number of spacecraft. As currently configured the software is capable of reading data (ASCII/CDF) for many existing missions. ViSBARD can be extended to interpret any number of ASCII and CDF formats through XML definitions, and we intend to add other formats. Each measurement is presented by a glyph (symbol or vector) at each point in time and at the position it was measured in the 3-D space. The ecliptic plane and, if appropriate, magnetospheric surfaces are presented to provide context. The software allows scrolling and zooming in time; the usual pan, zoom, and rotate in space; scaling of the data variables; a choice of color palettes; and 2-D graphs that scroll and scale in concert with the 3-D representation to aid the interpretation of the 3-D visualization. We plan to support stereo viewing. ViSBARD can display the "SSC" database that gives orbits of most currently operating SEC-related satellites as well as the COHOWeb database that contains most of the hourly averages of interplanetary spacecraft. A "combine" tool allows the user to assemble, e.g., plasma, magnetic field,

and orbit data from separate files for a single satellite into a one data set at any desired resolution. ASCII output makes it possible to save subsets or combined datasets for later or other use. Future plans include linking to distributed databases, as well as to solar images (ultimately via the Virtual Solar Observatory) and magnetospheric and ionospheric images. We will also include model output in the visualization. The project will provide open-source software to encourage contributions from the space physics community.

11.2 Solar Probe

Working with a NASA Academy student, E. Sittler in collaboration with the Flight Dynamics Branch at GSFC, has been leading the effort for developing a revised mission plan for Solar Probe from that developed by the Applied Physics Laboratory. Basically, they have developed a plan that will reduce mission risk, while enhancing the science return with an added measurement of the Sun's gravity field without any enhancement to the spacecraft radio link to Earth which will allow one to probe the core of the Sun and provide an independent observation of that provided by helioseismology measurements by SOHO. Basically, they go to Jupiter for a gravity assist to eject Solar Probe to the Sun, but instead of going to 4 R_S , go to 5 R_S . This will allow one to test the thermal models with a greater margin of safety. Also, during the first perihelion pass, they will perform a delta V maneuver to reduce the orbital period from 4 years to one year. This will greatly enhance the science return of the mission. Then if the thermal model check out ok, they can perform a delta V maneuver at aphelion or 2 AU and reduce perihelion from 5 R_S to 4 R_S . This will be possible by increasing the launch vehicle capability by going from an Atlas V to a DeltaIV Heavy. This added cost can be off-set by the reduced risk of the mission or replacing spacecraft structure with composites for example or using wireless communication between boxes and thus eliminate the mass from harnesses (and eliminate the risk of using harnesses).

11.3 Geospace Electrodynamic Connections (GEC) Mission

J. Grebowsky continued as Project Study Scientist for the definition of the GEC mission. K. Ford joined as the Project Formulation Manager. Attention is currently focusing on finalizing the overall mission architecture and bringing its cost into line with available resources. The challenge is to provide a multi-satellite mission with the capability of each spacecraft to make several deep dipping campaigns to ~ 130 km altitude. The ambitious goal of the mission is to resolve the time dependent and spatially structured plasma-neutral atmosphere interactions that play key roles in how the Sun's activity affects the near-Earth environment. This includes the desire to measure the effects in the low altitude region where the atmosphere is the dominant player in the coupling, which has yet to be explored with the full complement of in situ plasma and neutral particle instru-

ments to be flown on GEC. Preliminary design studies by industry last year demonstrated that a mission concept of four deep dipping-spacecraft was not feasible. This scenario far exceeded the cost cap and with the need to launch all spacecraft on one launch vehicle each spacecraft could not carry sufficient propulsion fuel to accomplish the deep dipping campaigns. New industry studies are currently underway (to be completed October 2003) to bring costs in line with available funds by reducing the number of spacecraft and/or relaxing spacecraft requirements without impacting the major science goals.

11.4 The Magnetospheric Constellation Mission (MCM)

(T. E. Moore, D. A. Roberts) The report of the MC-DRACO STDT has been distributed in various venues and via the WWW at <http://stp.gsfc.nasa.gov> during FY2003. In addition, four weeks of IMDC (Integrated Mission Design Center) studies have been conducted this year to refine the overall mission architecture and cost estimates. The approach taken was started with the ST-5 spacecraft design, add two instruments in support of MCM objectives, and to refine somewhat the mechanical design. Also, traditional costing approaches were extended to include industry experience with small production runs of other technological systems, via the PRICE-H model. The results of these studies have been very encouraging and have shown that a constellation of 30-39 ST-5 class spacecraft (~ 22 kg) can be placed in a set of constellation orbits that provide three seasons of plasma sheet coverage during which in $\sim 80\%$ of the constellation spacecraft are within 2 R_E of the neutral sheet at any given time. By adjusting the extent of the constellation; the critical region closer than 30 R_E can be sampled with the required spatial and temporal resolution. A novel dispenser vehicle design was developed by the IMDC, in which three separate dispenser systems each deploy 10-13 spacecraft independently, providing considerable propellant savings and added flexibility for mission optimization. All of this fits generally within the MC cost envelope, with the number of spacecraft depending on the amount of cost margin required.

11.5 Time History of Events and Macroscale Interactions during Substorms (THEMIS MIDEX)

D. G. Sibeck is a Co-investigator on the THEMIS mission. The primary objective of THEMIS is to elucidate which magnetotail process is responsible for substorm onset at the region where substorm auroras map ($10R_E$): (i) a local disruption of the plasma sheet current or (ii) that current's interaction with the rapid influx of plasma emanating from lobe flux annihilation at 25 R_E . THEMIS's five identical probes measure particles and fields on orbits which optimize tail-aligned conjunctions over North America while ground observatories time auroral breakup onset. Three inner probes at 10 R_E monitor current disruption onset, while two outer probes at 20 and 30 R_E remotely monitor plasma ac-

celeration due to lobe flux dissipation. D. Sibeck was selected as the Mission Scientist at GSFC. The spacecraft will launch in August 2006.

11.6 Magnetospheric MultiScale (MMS) Mission

S. Curtis continues as Project Scientist for the MMS mission which will for the first time access the smallest scales of plasma dynamics that are crucial to the understanding of the fundamental physics of magnetospheric dynamics and hence are needed to accurately predict space weather. The 4 spacecraft MMS mission is part of NASA's Solar Terrestrial Probes line and is the second multipoint mission in that line. The mission is a direct descendent of a 1995 MDEX bid by S. Curtis based on a mission concept that he originated in 1990. Progress is being made toward further refining the mission concept and toward selecting the mission's instrument providers.

11.7 New Millennium Program

New Millennium Program/ST-5 Mission. The New Millennium Program's Fifth Space Technology Mission, ST-5, will launch three small, ~ 25 kg, satellites into geosynchronous transfer orbit in early 2005. Their objective is to provide flight validation for a dozen new technologies critical for the future deployment and operation of constellations of small satellites. ST-5 will also test deployment and operations strategies necessary to make future "constellation-class" science missions economically viable. In order to validate the suitability of these small spacecraft as platforms for particles and fields measurements and to exercise the mission's autonomous operations capabilities, the ST-5 spacecraft will each carry a miniaturized magnetometer. ST-5 is now entered its integration and test phase with a launch readiness date of December 2004. J. A. Slavin is the ST-5 Project Scientist and G. Le leads the science validation portion of the mission.

ST-9 Solar Sail Demonstrator. A team, including A. Szabo, has been working in collaboration with JPL, MSFC, and Langley to design a mission to demonstrate the deployment and control of a solar sail powered craft. The ST-9 concept incorporates a ~ 1600 m² solar sail powering a ~ 20 kg spacecraft in near-geosynchronous orbit. Besides proving the viability of the various solar sail technologies, this mission will also characterize the space environment of the sail and determine how much future science observations would be effected by this new mode of propulsion. A. Szabo is a member of the pre-phase A solar sail proposal development team.

11.8 MESSENGER

Magnetic Fields Investigation. The MESSENGER mission to Mercury is now in the final stages of integration and test in preparation for a launch in the spring or summer of 2004. The purpose of this mission is to collect global information on the surface, interior, exosphere and magnetosphere of this least explored of

the terrestrial planets. The Principal Investigator is S. Solomon of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The lead institution for the spacecraft and mission operations will be the Johns Hopkins University Applied Physics Laboratory (JHU/APL). LEP scientists will be responsible for the vector magnetometer and the investigation of the planetary magnetic field and the magnetic structure of Mercury's magnetosphere. The LEP magnetic fields Co-investigators are M. H. Acuña and J. A. Slavin. MESSENGER will go into orbit around Mercury in 2009 following two earlier fly-by encounters.

MESSENGER XGRS. The group includes a number of co-investigators and participating scientists on the MESSENGER Mission (to the planet Mercury) X-ray/Gamma-Ray Spectrometer (XGRS). These individuals have supported the calibration and testing of the MESSENGER flight and backup detectors in support of the anticipated launch of the spacecraft in May or August 2004.

11.9 Mars Rover Program

A team of scientists representing NASA, universities, private industry, and other national laboratories have been organized and led by J. Trombka and colleagues in the Astrochemistry Branch to develop the design and implement the writing of a proposal for a Neutron/Gamma-ray system to respond to the Mars Smart Rover Announcement of Opportunity (AO) to be released in the Spring 2004.

National Institute of Justice/NASA Dual Technology Program. The National Institute of Justice (NIJ) and NASA/GSFC have teamed up to explore the use of NASA developed technologies to help criminal justice agencies and professionals solve crimes. The objective of the program is to produce instruments and communication networks that have applications within both NASA's space program and NIJ programs with state and local forensic laboratories. During this fiscal year, the efforts relative to the forensic science applications have concentrated on; corroborating the unique signature produced by gun powder residue using a number of different analytic techniques; determining minimum detectable limits needed for the identification of a number of crime scene forensic materials such as gun shot residue; blood, semen and glass; and the construction of a breadboard model of the XRF unit. The study relative NASA's planetary exploration program has involved a study of the design of the XRF unit for application to Mars Rover programs.

11.10 New Horizons Mission to Pluto

The Planetary Systems Branch (D. Jennings, D. Reuter, G. McCabe) have developed a near-infrared imaging spectrometer, called LEISA (Linear Etalon Imaging Spectral Array) which will fly on the New Horizons mission to Pluto. LEISA uses a wedged filter placed over a detector array to create spectral-spatial data cubes as the spacecraft scans the scene. LEISA is a focal plane

in the Ralph spectral imaging instrument on New Horizons that will conduct visible and infrared mapping of Pluto, Charon, and Kuiper Belt objects. The LEISA development for New Horizons is in collaboration with the Goddard Detector Systems Branch, along with Ball Aerospace Corporation and Southwest Research Institute.

11.11 Multi-Scale Global Simulations of the Magnetosphere

S. Curtis, D. Spicer and A. Klimas are working on an approach to incorporate multiscale physics into global MHD simulation codes by global and local resistivities. The resistivities represent a parameterization of microscale processes that can not be captured within the computational bandwidth of presently available platforms. The simulation code in which the resistivities will be embedded is an unstructured mesh code with adaptivity capability in the mesh. They anticipate sufficient adaptive grid refinement to reduce the intrinsic numerical resistivity of the code to well below the resistivity resulting from the applied global and local resistivities. In this manner, it will be possible to explore the consequences of microscale processes on global magnetospheric dynamics using present day super computers.

11.12 Autonomous Nano Technology Swarm (ANTS)

A team under the leadership of S. Curtis has been working during the past year on a new space architecture approach to many spacecraft missions. This effort has been funded by NASA's Revolutionary Aerospace Systems and Concepts (RASC) program and the mid-term report was very favorably received by the Space Architect's office at NASA HQ. The specific application of the ANTS architecture being studied is the Prospecting Asteroid Mission (PAM). PAM is a fleet of 1000 autonomous solar sailing nano sciencecraft (1 kg spacecraft specilaized to carry a single instrument). The deployed solar sail for each spacecraft is 100 square meters. There are 10 classes of specilaized workers grouped in subwarms of 100. Each subswarm sequentially visits asteroids in the main asteroid belt. Prior to deployment at the Earth-Moon lagrange point, the reconfigurable spacecraft swarm fits in a one meter cube.

11.13 Science and Related Technology Partnership with an Historically Black University

A partnership with the Electrical Engineering Department at Morgan State University in Maryland has been started under the leadership of S. Curtis. The objectives are two fold: (1) To further develop radio astronomy and related radio wave application hardware capabilities in the Planetary Magnetospheres Branch, and (2) to draw upon Morgan State's expertise in MEMS technology to further GSFC interests in reconfigurable spacecraft and instruments. In the first area, we have now a graduate coop student from the Morgan State Department of Electrical Engineering working in our radio

astronomy hardware lab with W. Farrell. In the second area, we had a visiting professor work with us this summer on MEMS applications to reconfigurable instruments and spacecraft.

12 EDUCATIONAL OUTREACH AND TECHNOLOGY TRANSFER

Classroom Program for 3D Topographical Models. J. Keller with colleagues from Earth Science's geodynamics branch (H. Frey, J. Roark, S. Sakimoto, and S. Stockman code, 921), have begun a program to explore the use of 3-dimensional topographical models in the classroom as an educational aid. These models are created by translating laser altimeter data from the Mars Orbital Laser Altimeter (MOLA), for example, into scale 3-dimensional models. Sets of models of Olympus Mons on Mars and the Hawaiian island chain have been assembled into kits to be distributed among middle school teachers for use in their classrooms. The models are innovative in that they will provide students with a tactile representation of the three-dimensional character of a planetary surface, which is often difficult to visualize from 2-dimensional maps. Along with the models, associated lesson plans are being designed to help students and teachers understand topics related to topography such as scale, shape, landform evolution, contour, slope, and exaggeration.

Visiting Faculty Member. M. Iannone, a faculty member at Millersville University, Millersville, PA, worked with R. Cody, L. Stief, A. Pimentel, W. Payne and F. Nesbitt on reactions involving the ethyl radical. Dr. Iannone participated as part of the 2003 NASA Faculty Fellowship Program.

Education and Public Outreach. P. Romani participated in Challenger Center's Journey through the Universe Program for the Washington D.C. Public School system. This program includes classroom visits by scientists and engineers. He visited three schools and made eight presentations. He also made a three-day outreach trip to the Amherst, Massachusetts school system and gave classroom presentations in grades ranging from second grade to tenth grade. He worked with teachers and their students at Glenarden Woods Elementary School in Glenarden, Maryland. The students studied ancient China in a yearlong thematic unit that involved language arts, social studies, and art. To this program a week-long unit on rockets, in honor of the Chinese discovery of gunpowder, was added. The students did hands-on experiments and learned about the numerous "firsts" in rocketry that the ancient Chinese accomplished (multiple rocket launchers, multi-stage rockets, etc.)

T. A. Livengood has engaged in numerous classroom visits and public talks presenting planetary and space science to the public, including personal research with the infrared heterodyne spectroscopy group at GSFC, and collaborates in the development of curriculum materials adopted for the sixth grade in the Washington, D.C. school system and in other communities nationally. Audiences in 2002-2003 included approximately

1100 students in classroom visits, approximately 1000 parents, children, and teachers in Family Science Night presentations, and about 300 teachers in workshop and keynote presentations. J. Delgado continued his work in the heterodyne spectroscopy laboratory during the 2002-2003 academic year, completing his undergraduate degree this year. He is continuing his work with the IR heterodyne group for a year after graduation, assembling and testing laser systems, contributing to development efforts for the HIPWAC instrument, and accomplishing laboratory spectroscopy of gases relevant to outer planet atmospheres under the guidance of T. Kostiuik and W. Blass. Two high school students, Kyle Carson and Joseph Smith, worked with T. Hewagama under the SHARP program during the summer of 2003, implementing a graphical user interface for line-by-line infrared radiative transfer software.

Outreach Talk. The WIND/MFI team continues to support outreach to students, especially during proclaimed days for that purpose. For example, R. Lepping gave a talk on Sun-to-Earth Connections on Sun-Earth Day, March 18, 2003, at the Benjamin Tasker Middle School in Bowie MD, to eighth graders, with some lively discussion following. The talk employed actual solar and solar wind data from spacecraft, usually from the Web, and addressed some of the problems that scientists attempt to solve in space physics.

NASA Eclipse Home Page. F. Espenak is the webmaster of the NASA Eclipse Home Page at <http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html>. During May, this web site received several million hits due to the tremendous interest generated by the total lunar eclipse of May 9 and the annular solar eclipse on May 31. He assisted the Goddard Office of Public Affairs in the development of eclipse animation's to distribute to news media nationally for the eclipses. F. Espenak also gave a series of television interviews about the eclipse on a live feed from NASA Headquarters.

Laboratory Education/Outreach Website Development. D. Taggart, M. Collier, and R. Lepping are leading an effort, joined by various members of the Lab, to continue the development of the Lab's Education/Outreach Website. The site attempts to appeal to a broad audience, but targets high school students in particular and highlights the scope of the Laboratory's research and its collaborations. This team, D. Taggart in particular, continues to increase the number of major search engines from which the site can be accessed. The site's page, called "Current Events," which highlights science events in the news that pertain to the Lab's areas of interest, continues to receive good interest from the public. The site's "publication list" continues to grow as more books, usually in popular language, in our fields are published and reviewed by the staff.

Mentoring a Summer Student. N. Gopalswamy mentored a Summer Intern, A. Williams, a computer science student from South Carolina State University. She participated in the Summer Institute in Engineering and Computer Applications (SIECA) program. The intern

had the opportunity to learn about the Sun-Earth connections and how solar disturbances can affect the human society. She also helped the research activities of N. Gopalswamy by measuring the drift rates of interplanetary type II bursts detected by the Wind/WAVES experiment to obtain the speed of shocks responsible for the type II bursts. The shock speeds were then compared with the speeds of CMEs observed by the SOHO mission's coronagraph.

N. Gopalswamy mentored a summer student S. Tun, who returned for the second time for summer undergraduate research. The research involved surveying the white-light CMEs that occurred between 1996 and 2002 searching for interacting CMEs. A list of candidate interaction events was generated for further study. This list will be compared against movies of inner coronal images to identify the solar sources of the interacting candidates. List of multiple interacting events was also generated, showed increased CME interaction rate during solar maximum.

F. Espenak mentored summer student L. Williams through the National Space Club. Williams worked with Espenak to expand the NASA Eclipse Home Page (see Web site below). In particular, the World Atlas of Solar Eclipse Paths (<http://sunearth.gsfc.nasa.gov/eclipse/SEAtlas/SEAtlas.html>) was expanded to include all eclipse paths from 1000 BC to AD 3000. Web site is: (<http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html>).

Z. Chase, an undergraduate student enrolled in the chemistry/chemical engineering dual degree program at Morehouse College and the Georgia Institute of Technology, worked with W. Payne, R. Cody, and L. Stief during the summer. Chase contributed to the research efforts of the kinetics team as part of the NASA-Morehouse College project "Strategic Preparedness in Advancing Careers in Engineering."

A. Roberts mentored a summer high school student, M. Luckyanova (Montgomery Blair HS), who worked on the initial applications of a new method for visualizing space physics data. She analyzed the solar wind upstream of the Earth to determine its structure. This research will be the basis of an Intel Science Competition project in Spring 2004.

For six weeks, starting in late June 2002, A. Quivers, a gifted high school student under the National Space Club Scholars Program, assisted R. Lepping (mentor) and D. Berdichevsky by contributing to an analysis of the errors produced in the fitting of interplanetary magnetic clouds using a "force free" scheme. In the process, the student developed various IDL programs to help in the interpolation and extrapolation of parameter error-values to make the overall program more effective. He also helped to re-fit the parameters of many previously studied magnetic clouds using an advanced program that provides better means of estimating the quality of the fits. The results are expected to be published.

As part of the National Space Club Scholars program, another gifted high school student (T. Ferguson) helped R. Lepping and D. Berdichevsky analyze the so-

lar wind velocity observed in interplanetary magnetic clouds. During six weeks starting in late June 2002, the student developed various IDL programs to understand the relationship between velocity profiles and magnetic cloud expansion. This feature led to the discovery that clouds primarily expand along the XGSE axis rather than in the directions perpendicular to the ecliptic plane. The student also contributed to the development of various parts of the Lab's Education and Public Outreach website, emphasizing "Student Activities."

Technology Outreach Programs. J. Trombka is participating in a governmental group which has been assembled to study unattended and remote instrument technology. The results of the first conference sponsored by this group in 2002 was published this fiscal year 2002 conference and planning of the next Conference to be held April 2004 is underway. The 2004 conference will be co-sponsored by NASA, the Department of Energy, the Department of Justice, the Department of State, the Department of Transportation, and the National Academy of Science.

Advisory Activities. T. Kostiuik serves on the NASA Keck/Infrared Telescope Facility Management Operations Working Group (MOWG).

REFERENCES

- Acuña, M. H., et al., The Magnetic Field of Mars: Summary of Results from the Aerobraking and Mapping Orbits, *J. Geophys. Res.*, 106, 23,403- 23,417, 2001.
- Acuña, M. H., B. J. Anderson, C. T. Russell, P. Wasilewski, G. Kletetschka, L. Zanetti and N. Omid, NEAR Magnetic Field Observations at Eros: First Measurements from the Surface of an Asteroid, *Icarus*, 155, 220-228, 2002.
- Aikin, A. C., J. M. Grebowsky, and J. P. Burrows, GOME Metallic Ion and Neutral Species Measurements, *Adv. Space Res.*, in press, 2003.
- Araneda, J. A., A. F.-Viñas, and H. F. Astudillo, Proton Core Temperature Effects on the Relative Drift and Anisotropy Evolution of the ion Beam Instability in the Fast Solar Wind, *J. Geophys. Res.*, 107 (A12), 1453, 2002.
- Aksnes, A., J. Stadsnes, J. Bjordal, N. Ostgaard, R. Vondrak, et al., Instantaneous Ionospheric Global Conductance Maps During an Isolated Substorm, *Ann. Geophysicae*, 20, 1181, 2002.
- Aksnes, A., J. Stadsnes, G. Lu, A. Richmond, N. Ostgaard, T. Rosenberg, D. Detrick, G. Germany, R. Vondrak, and M. Schulz, Effects of Energetic Electrons on the Electrodynamics in the Ionosphere, *Annales Geophysicae*, in press, 2003.
- Baker, D. N., Telescopic and Microscopic Views of the Magnetosphere: Multispacecraft Observations, *Space Sci. Rev.*, Special Issue, in press, 2003.
- Banfield, J. L., and M. D. Smith, Multiple Emission Angle Surface-atmosphere Separations of Thermal Emission Spectrometer Data, *Icarus*, 161, 47-65, 2003.
- Banfield, D., B. J. Conrath, M. D. Smith, P. R. Christensen, and R. J. Wilson, Forced Waves in the Martian Atmosphere from MGS/TES Nadir Data, *Icarus*, 161, 319-345, 2003.
- Barrow, C. H., A. Lecacheux, and R. J. MacDowall, Jovicentric Latitude Effect on the HOM Radio Emission Observed by Ulysses/URAP at 5 AU from Jupiter, *Ann. Geophys.*, 20, 599, 2002.
- Benson, R. F. and V. A. Osherovich, Application of Ionospheric Topside-Sounding Results to Magnetospheric Physics and Astrophysics, *Proc. of the Ionospheric Effects Symposium*, May 7-9, 2002, Alexandria, VA, 2002.
- Benson, R. F., and V. A. Osherovich, Application of Ionospheric Topside-Sounding Results to Magnetospheric Physics and Astrophysics, *Radio Sci.*, in press, 2003.
- Benson, R. F., V. A. Osherovich, J. Fainberg, and B. W. Reinisch, Classification of IMAGE/RPI-stimulated Plasma Resonances for the Accurate Determination of Magnetospheric Electron-density and Magnetic Field Values, *J. Geophys. Res.*, 108(A5), 1207, doi:10.1029/2002JA009589, 2003.
- Berchem, J., et al., Dayside Proton Aurora: Comparison Between Global MHD Simulations and IMAGE Observations, *Space Sci. Rev.*, Special Issue, in press, 2003.
- Berdichevsky, D. B., C. J. Farrugia, B. J. Thompson, R. P. Lepping, D. V. Reames, M. L. Kaiser, J. T. Steinberg, S. P. Plunkett, and D. J. Michels, Halo-coronal Mass Ejections Near the 23rd Solar Minimum: Lift-off, Inner Heliosphere, and In-situ (1 AU) Signatures, *Ann. Geophys.*, accepted, 2002.
- Berdichevsky, D. B., R. P. Lepping, and C. J. Farrugia, On Geometric Considerations of the Evolution of Magnetic Flux Ropes, *Phys. Rev. E*, 67(3), 036405, 2003.
- Berdichevsky, D. B., C. J. Farrugia, R. P. Lepping, I. G. Richardson, A. B. Galvin, R. Schwenn, D. V. Reames, K. W. Ogilvie, and M. L. Kaiser, Solar-Heliospheric-Magnetospheric Observations on March 23 - April 26, 2001: Similarities to Observations in April 1979, *APS Proc. of Solar Wind X*, Pisa, Italy, June 2002, 2003.
- Bernstein, M. P., M. H. Moore, J. E. Elsila, S. A. Sandford, L. J. Allamandola, and R. N. Zare, Side Group Addition to the Polycyclic Aromatic Hydrocarbon Coronene by Proton Irradiation in Cosmic Ice Analogs, *Astrophys. J.*, 582, L25-L29, 2002.
- Bernstein, M. P., J. E. Elsila, J. P. Dworkin, S. A. Sandford, L. J. Allamandola, and R. N. Zare, Side Group Addition to the PAH Coronene by UV Photolysis in Cosmic Ice Analogs, *Astrophys. J.*, 576, 1115-1120, 2002.
- Bernstein, M. P., J. P. Dworkin, S. A. Sandford and L. J. Allamandola, Ultraviolet Irradiation of the Polycyclic Aromatic Hydrocarbon (PAH) Naphthalene in H₂O. Implications for Meteorites and Biogenesis, *Adv. Space Res.*, 30, 1501-1508, 2002.
- Bernstein, M. P., J. P. Dworkin, G. W. Cooper, G. W., S. A. Sandford and L. J. Allamandola, Racemic Amino

- Acids from the Ultraviolet Photolysis of Interstellar Ice Analogues, *Nature*, 416, 401-403, 2002.
- Bertucci, C., C. Mazelle, J. A. Slavin, C. T. Russell, and M. H. Acuña, Magnetic Field Enhancement at Venus: Evidence for a Magnetic Pileup Boundary, *Geophys. Res. Lett.*, 30(17), 1876, doi:10.1029/2003GL017271, 2003.
- Bertucci, C., C. Mazelle, D. H. Crider, D. Vignes, M. H. Acuña, D. L. Mitchell, R. P. Lin, J. E. P. Connerney, H. Rème, P. A. Cloutier, N. F. Ness, and D. Winterhalter, Magnetic Field Draping Enhancement at the Martian Magnetic Pileup Boundary from Mars Global Surveyor Observations, *Geophys. Res. Lett.*, 30, 2, 1099, doi:10.1029/2002GL015713, 2003.
- Bilitza, D., N. Papitashvili, J. Grebowsky, and W. Schar, Ionospheric Data for Two Solar Cycles Available Online, in *Proc. of the the IRI Task Force Activity 2001*, ed. By S. M. Radicella, UNESCO and IAEA, Abdus Salam International Centre for Theoretical Physics, Trieste, pp 23-28, 2002.
- Bilitza, D., B. Reinisch, R. Benson, J. Grebowsky, N. Papitashvili, X. Huang, W. Schar and K. Hills, Online Data Base of Satellite Sounder and Insitu Measurements Covering Two Solar Cycles, *Adv. Space Res.*, 31, 769-774, 2003.
- Bilitza, D., B. Reinisch, R. Benson, J. Grebowsky, N. Papitashvili, X. Huang, and W. Schar, Online Data Base of Satellite Sounder and In-situ Measurements Covering Two Solar Cycles, *Adv. Space Res.*, 31(3), 769-774, 2003.
- Bilitza, D., X. Huang, B. W. Reinisch, R. F. Benson, W. B. Schar, and K. Hills, TOPIST - Automated Processing of ISIS Topside Ionograms, *Radio Sci.*, in press, 2003.
- Birn, J., J. C. Dorelli, M. Hesse, and K. Schindler, Thin Current Sheets and Loss of Equilibrium: 3d Theory and Simulations, *J. Geophys. Res.*, submitted, 2002.
- Birn, J., K. Schindler, M. Hesse, Formation of Thin Current Sheets in the Magnetotail: Effects of Propagating Boundary Deformations, *J. Geophys. Res.*, Vol. 108, 1337, 2002.
- Blakeslee, R. J., D. M. Mach, M. C. Desch, R. A. Goldberg, W. M. Farrell, and J. G. Houser, The Altus-Cumulus Electrification Study (ACES): A UAV Based Science Demonstration, *AIAA's 1st Technical Conference and Workshop on Unmanned Aerospace Vehicles, Systems, Technologies, and Operations*, Portsmouth, Virginia, 20-23 May 2002, AIAA-2002-3405, 2002.
- Blakeslee, R. J., C. L. Croskey, M. D. Desch, W. M. Farrell, R. A. Goldberg, J. G. Houser, H. S. Kim, D. M. Mach, J. D. Mitchell, and J. C. Stoneburner, The Altus Cumulus Electrification Study (ACES): A UAV-Based Science Demonstration, *Proceedings of the 12th International Conference on Atmospheric Electricity*, Versailles, France, June 9-13, 2003.
- Bonev, B. P., M. J. Mumma, N. DelloRusso, E. L. Gibb, M. A. DiSanti, and K. Magee-Sauer, A Quantitative Analysis of OH Prompt Emission in Three Comets: The 3046 cm⁻¹ Quadruplet and its use in Determining Cometary Water Production Rates, *BAAS*, 35 (4), 967, 2003.
- Boynton, W. V., W. C. Feldman, S. W. Squyres, T. Prettyman, J. Brückner, L. G. Evans, R. C. Reedy, R. D. Starr, J. R. Arnold, D. M. Drake, P. A. J. Englert, A. E. Metzger, I. Mitrofanov, J. I. Trombka, C. d'Uston, H. Wänke, O. Gasnault, D. K. Hamara, D. M. Janes, R. L. Marcialis, S. Maurice, I. Mikheeva, G. J. Taylor, R. Tokar, and C. Shinohara, Distribution of Hydrogen in the Near-Surface of Mars: Evidence for Subsurface Ice Deposits, *Science*, 297, 81, 2002.
- Boynton, W. V., G. J. Taylor, L. G. Evans, W. C. Feldman, I. G. Mitrofanov, R. C. Reedy, S. W. Squyres, R. Starr, D. K. Hamara, D. M. Janes, and K. Kerry, Mars Odyssey GRS Team, Results from the Mars Odyssey Gamma-Ray Spectrometer: Distribution of Volatile and Rock-forming Elements, *Am. Astron. Soc.*, DPS meeting, 35, 08.01, 2003.
- Boynton, W. V., G. J. Taylor, D. Hamara, K. Kerry, D. Janes, J. Keller, W. Feldman, T. Prettyman, R. Reedy, J. Bruckner, H. Wanke, L. Evans, R. Starr, S. Squyres, S. Karunatillake, O. Gasnault, Compositional Diversity of the Martian Crust: Preliminary Data from the Mars Odyssey Gamma-Ray Spectrometer, *34th Annual Lunar and Planetary Science Conference*, March 17-21, League City, Texas, No. 2108, 2003.
- Brain, D. A., F. Bagenal, M. H. Acuña, J. E. P. Connerney, D. H. Crider, C. Mazelle, D. L. Mitchell, N. F. Ness, Observations of Low-frequency Electromagnetic Plasma Waves Upstream from the Martian Shock, *J. Geophys. Res.*, 107, (A6), doi:10.1029/2000JA000416, 2002.
- Brandt, P. S., Ohtani, D. G. Mitchell, M.-C. Fok, E. C. Roelof, and R. Demajistre, Global ENA Observations of the Storm Main Phase Ring Current: Implications for Skewed Electric Fields in the Inner Magnetosphere, *Geophys. Res. Lett.*, in press, 2002.
- Brasunas, J. C., High-Tc Superconducting IR Detectors, in *Handbook of High Temperature Superconductor Electronics.*, ed. Neeraj Khare, Marcel Dekker, Inc, 2003.
- Brasunas, J. C. and B. Lakew, Long-term Stability of the Cassini Fourier Transform Spectrometer in Route to Saturn, in *Recent Research Developments in Optics*, ed. A. Gayathri, Research Signpost (Kerala, India), in press, 2003.
- Brasunas, J. C., A Simple Etalon-stabilized Visible Laser Diode, *Meas. Sci. Technol.* 13: N67-N71, 2002.
- Brasunas, J. C., Phase Anomalies in Fourier-transform Spectrometers: an Absorbing Beam Splitter is Neither Sufficient nor Necessary, *Appl. Opt.* 41 (13): 2481-2487, 2002.
- Brasunas, J. C., B. Lakew, and R. Fettig, A Comment on the Reported Detectivity of a New Uncooled Thermal Infrared Detector, *Sensors and Actuators A*, 96, 211-213, 2002.

- Brosius, J. W., E. Landi, J. W. Cook, J. S. Newmark, N. Gopalswamy, and A. Lara, Measurements of Three-dimensional Coronal Magnetic Fields from Coordinated Extreme-ultraviolet and Radio Observations of a Solar Active Region Sunspot, *Astrophys. J.*, 574, 453, 2002.
- Burch, J. L., The First Two Years of IMAGE, *Space Sci. Rev.*, Special Issue, in press, 2003.
- Burlaga, L. F. and M. Forman, Large-scale Speed Fluctuations at 1 AU on Scales from 1 Hour to 1 Year: 1999 and 1995, *J. Geophys. Res.*, in press, 2002.
- Burlaga, L. F., N. F. Ness, F. B. McDonald, J. D. Richardson, and C. Wang, Voyagers 1 and 2 Observations of Magnetic Fields and Associated Cosmic Ray Variations from 2000 through 2001; 60- 87 AU, *Astrophys. J.*, in press, 2002.
- Burlaga, L. F., N. F. Ness, Y.-M. Wang, and N. R. Sheeley, Heliospheric Magnetic Field Strength and Polarity from 1 to 81 AU During the Ascending Phase of Solar Cycle 23, *J. Geophys. Res.*, 107(A11), No.-1410, 2002a.
- Burlaga, L. F., N. F. Ness, Y.-M. Wang, and N. R. Sheeley, Jr., Voyager Studies of the hmf to 81 AU During the Ascending Phase of Solar Cycle 23, in *Solar Wind X*, Pisa, Italy, 2002.
- Burlaga, L. F., O. C. St Cyr, and S. Plunkett, Successive CME's and Complex Ejecta, *J. Geophys. Res.*, 107(A10), No.-1266, 2002b.
- Burlaga, L. F., J. D. Richardson, and C. Wang, Speed Fluctuations near 60 AU on Scales from 1 day to 1 year: Observations and Model, *J. Geophys. Res.*, 107, NO. A10, 1328, doi:10.1029/2002JA009379, 2002c.
- Burlaga, L. F., N. F. Ness, E. C. Stone, F. B. McDonald, M. H. Acuña, R. P. Lepping, J. E. C. Connerney, Search for the Heliosheath with Voyager 1 Magnetic Field Strength Measurements, *Geophys. Res. Lett.*, accepted, 2003a.
- Burlaga, L. F., D. Berdichevsky, N. Gopalswamy, R. P. Lepping, and T. Zurbuchen, Merged Interaction Regions at 1 AU, *J. Geophys. Res.*, accepted, 2003b.
- Burlaga, L. F., N. Ness, E. Stone, F. McDonald, M. Acuña, A. R. Lepping, and J. Connerney, Search for the heliosheath with Voyager 1 Magnetic Field Measurements, *Geophys. Res. Lett.*, submitted, 2003a.
- Burlaga, L. F., N. F. Ness, F. B. McDonald, J. D. Richardson, and C. Wang, Voyager 1 and 2 Observations of Magnetic Fields and Associated Cosmic-ray Variations from 2000 Through 2001: 60-87 AU, *Astrophys. J.*, 582(1), 540-549, 2003b.
- Burlaga, L. F., N. F. Ness, and J. D. Richardson, Sectors in the Distant Heliosphere: Voyager 1 and 2 Observations from 1999 - 2002 Between 57 and 83 AU, *J. Geophys. Res.*, in press, 2003c.
- Burlaga, L. F., C. Wang, and N. F. Ness, A Model and Observations of the Multifractal Spectrum of the Heliospheric Magnetic Field Strength Fluctuations Near 40 AU, *Geophys. Res. Lett.*, 30(10), No.-1543, 2003d.
- Burlaga, L. F., C. Wang, N. F. Ness, and J. D. Richardson, Evolution of Magnetic Fields in Corotating Interaction Regions from 1 to 95 AU: Order to Chaos, *Astrophys. J.*, in press, 2003e.
- Burlaga, L. F., C. Wang, J. Richardson, and N. F. Ness, Large-scale Magnetic Field Fluctuations and Development of the 1999 - 2000 GMIR: 1 to 60 AU, *Astrophys. J.*, in press, 585, 1158, 2003f.
- Burlaga, L. F., C. Wang, J. D. Richardson, and N. F. Ness, Evolution of Magnetic Fields in Corotating Interaction Regions from 1 to 95 AU: Order to Chaos, *Astrophys. J.*, 590(1), 554-566, 2003g.
- Burlaga, L. F., C. Wang, J. D. Richardson, and N. F. Ness, Large-scale Magnetic Field Fluctuations and Development of the 1999-2000 Global Merged Interaction Region: 1-60 AU, *Astrophys. J.*, 585(2), 1158-1168, 2003h.
- Carpenter, D. L., M. A. Spasojevic, T. F. Bell, U. S. Inan, V. S. Sonwalker, B. W. Reinisch, I. A. Galkin, R. F. Benson, J. L. Green, S. F. Fung, W. W. L. Taylor, and S. A. Boardsen, Radio Sounding the Earth's Plasmasphere and Excitation of the Whistler and Z Modes by the Radio Plasma Imager (RPI) Instrument on the IMAGE Satellite, *Proc. of the Ionospheric Effects Symposium*, May 7-9, 2002, Alexandria, VA, 2002.
- Carpenter, D. L., M. A. Spasojevic, T. F. Bell, U. S. Inan, B. W. Reinisch, I. A. Galkin, R. F. Benson, J. L. Green, S. F. Fung, and S. A. Boardsen, Small-scale Field-aligned Plasmaspheric Density Structures Inferred from RPI on IMAGE, *J. Geophys. Res.*, 107(A9), 1258, doi:10.1029/2001JA009199, 2002.
- Carpenter, D. L., T. F. Bell, U. S. Inan, R. F. Benson, V. S. Sonwalkar, B. W. Reinisch, and D. L. Gallagher, Z-mode Sounding Within Propagation "cavities" and Other Inner Magnetospheric Regions by the RPI Instrument on the IMAGE Satellite, *J. Geophys. Res.*, submitted, 2003.
- Castro Cerón, J. M., A. J. Castro-Tirado, J. Gorosabel, J. Hjorth, J. U. Fynbo, B. L. Jensen, H. Pedersen, M. I. Andersen, M. López-Corredoira, O. Suárez, Y. Grosdidier, J. Casares, D. Pérez-Ramírez, B. Milvang-Jensen, G. Mallén-Ornelas, A. Fruchter, J. Greiner, E. Pian, P. M. Vreeswijk, S. D. Barthelmy, T. Cline, F. Frontera, L. Kaper, S. Klose, C. Kouveliotou, Hartmann, D. H. Hurley, K. Masetti, N. Mazets, E. Palazzi, E. Park, H. S. Rol, E. I. Salamanca, N. Tanvir, J. I. Trombka, R. A. M. J. Wijers, G. G. Williams, E. Van den Heuvel, The Bright Optical Afterglow of the Long GRB 001007, *Astron. and Astrophys.*, v.393, p.445-451, 2002.
- Chandler, M. O. and T. E. Moore, Observations of the Geopause at the Equatorial Magnetopause: Density and Temperature, *Geophys. Res. Lett.*, in press, 2003.
- Chandler, M. O. and L. A. Avanov, Observations at Low Latitudes of Magnetic Merging Signatures Within a Flux Transfer Event During a Northward IMF, *J. Geophys. Res.*, in press, 2003.

- Chanover, N. J., C. M. Anderson, C. P. McKay, P. Rannou, D. A. Glenar, J. J. Hillman, and W. E. Blass, Probing Titan's Lower Atmosphere with Acousto-Optic Tuning, *Icarus*, 163, 150-163, 2003.
- Chao, J.-K., D. J. Wu, C. H. Lin, Y. H. Yang, X. Y. Wang, M. Kessel, S. H. Chen, and R. P. Lepping, Models for the Size and Shape of the Earth's Magnetopause and Bow Shock, Space Weather Study Using Multipoint Techniques, *Proceedings of COSPAR Colloquium*, ed. L.-H. Lyu, Pergamon Press, 127, 2002.
- Chang, S.-W., J. D. Scudder, K. Kudela, H. E. Spence, J. F. Fennell, R. P. Lepping, R. P. Lin, and C. T. Russell, Reply to Comment on 'Mev Magnetosheath Ions Energized at the Bow Shock, by J. Chen, T. A. Fritz, and R. B. Sheldon, *J. Geophys. Res.*, submitted, 2003.
- Chen, S.-H., and T. E. Moore, Dayside Flow Bursts in the Earth's Magnetosphere, *J. Geophys. Res.*, in review, 2003.
- Chanover, N. J., T. Temma, G. Bjoraker and T. Hewagama, Latitudinal Variations of Saturn's Near-Infrared Spectrum, *AAS/Division for Planetary Sciences Meeting*, 35, 40.02, 2003.
- Christensen, P. R., J. L. Bandfield, J. F. Bell III, N. Gorelick, V. E. Hamilton, A. Ivanov, B. M. Jakosky, H. H. Kieffer, M. D. Lane, M. C. Malin, T. McConnochie, A. S. McEwen, H. Y. McSweeney Jr., G. L. Mehall, J. E. Moersch, K. H. Nealson, J. W. Rice Jr., M. I. Richardson, S. W. Ruff, M. D. Smith, T. N. Titus, and M. B. Wyatt. Morphology and Composition of the Surface of Mars: Mars Odyssey THEMIS results, *Science*, 300, 2056-2061, 2003.
- Clarke, J. T., J. Ajello, G. E. Ballester, L. Ben Jaffel, J. E. P. Connerney, J.-C. Gerard, G. R. Gladstone, D. Grodent, W. Pryor, J. Trauger, and J. H. Waite, Jr., Ultraviolet Emissions from the Magnetic Footprints of Io, Ganymede, and Europa on Jupiter, *Nature*, 415, 997 - 1000, 2002.
- Cody, R. J., W. A. Payne, Jr., R. P. Thorn, Jr., F. L. Nesbitt, M. A. Iannone, D. C. Tardy, and L. J. Stief, Rate Constant for the Recombination Reaction $\text{CH}_3 + \text{CH}_3 \rightarrow \text{C}_2\text{H}_6$ at $T = 298$ and 202 K, *J. Phys. Chem. A*, 106, 6060, 2002.
- Cody, R. J., P. N. Romani, F. L. Nesbitt, M. A. Iannone, D. C. Tardy, and L. J. Stief, Rate Constant for the Reaction $\text{CH}_3 + \text{CH}_3 \rightarrow \text{C}_2\text{H}_6$ at $T = 155$ K and Model Calculations of CH_3 Abundance in the Atmospheres of Saturn and Neptune, *J. Geophys. Res.*, In press, 2003.
- Collier, M. R., T. E. Moore, D. Simpson, A. Roberts, A. Szabo, S. Fuselier, P. Wurz, M. A. Lee, and B. Tsurutani, An Unexplained 10 degree - 40 degree Shift in the Location of Some Diverse Neutral Atom Data at 1 AU, *Adv. Space Res.*, in press, 2003.
- Collier, M. R., T. E. Moore, K. Ogilvie, D. J. Chornay, J. Keller, S. Fuselier, J. Quinn, P. Wurz, M. Wuest, and K. C. Hsieh, Dust in the Wind: The Dust Geometric Cross Section at 1 AU based on Neutral Solar Wind Observations, *Solar Wind 10*, in press, 2003.
- Collier, M. R., D. J. Chornay, J. W. Keller, M. Coplan, N. J. Dionne, E. M. Brahim, F. Herrero, J. Hirman, J. Houser, J. Moore, and J. A. Slavin, Tomographic Imaging of Electron Distributions: Leveraging Computing Power Advances to Produce Inexpensive, Low-power, Lightweight, and Robust Instrumentation, *Rev. Sci. Instrum.*, 74, 1002-1007, 2003.
- Collier, M. R., T. E. Moore, D. Simpson, A. Roberts, A. Szabo, S. Fuselier, P. Wurz, M. A. Lee and B. T. Tsurutani, An Unexplained 10-40 Degree Shift in the Location of Some Diverse Neutral Atom Data at 1 AU, *Adv. Space Res.*, in press, 2003.
- Collier, M. R., Are Magnetospheric Suprathermal Particle Distributions (kappa functions) Inconsistent with Maximum Entropy Considerations? *Adv. Space Res.*, in press, 2003.
- Connerney, J. E. P., et al., The Global Magnetic Field of Mars and Implications for Crustal Evolution, *Geophys. Res. Lett.*, 28, 4015-4018, 2001.
- Connerney, J. E. P. and T. Satoh, The H^3+ Ion: A Remote Diagnostic of the Jovian Magnetosphere, *Phil. Trans. R. Soc. Lond.*, 358, 2471-2483, 2000.
- Connerney, J. E. P., M. H. Acuña, N. F. Ness, T. Spohn, and G. Schubert, Mars Crustal Magnetism, in *The Solar Wind Interaction with Mars*, Eds. D. Winterhalter. M. H. Acuña, et al., Kluwer Academic Publishers, 2003.
- Cottin, H., M. H. Moore, and Y. Benilan, Photodestruction of Relevant Interstellar Molecules in Ice Mixtures, *Astrophys. J.*, 590, 874-881, 2003.
- Crider, D. and R. Vondrak, Hydrogen Migration to the Lunar Poles by Solar Wind Bombardment of the Moon, *Advances Space Res.*, Vol. 30, No. 8, pp. 1869-1874, 2002.
- Crider, D. and R. Vondrak, Space Weathering Effects on Lunar Cold Trap Deposits, *J. Geophys. Res.*, Vol. 108, No. E7, 5079, 10.1029/2002JE002030, 30 July 2003.
- Crider, D. and R. Vondrak, Space Weathering of Ice Layers in Lunar Cold Traps, *Adv. Space Res.*, Vol. 31/11, pp. 2293-2298, 2003.
- Crider, D. H., M. H. Acuña, J. E. P. Connerney, D. Vignes, N. F. Ness, A. M. Krymskii, T. K. Breus, H. Rème, C. Mazelle, D. L. Mitchell, R. P. Lin, P. A. Cloutier, and D. Winterhalter, Observations of the Latitude Dependence of the Location of the Martian Magnetic Pileup Boundary, *Geophys. Res. Lett.*, 29, 8, 10.1029/2001GL013860, 2002.
- Deamer, D. W., J. P. Dworkin, S. A. Sandford, M. P. Bernstein, and L. J. Allamandola, The First Cell Membranes, *Astrobiology*, 2, 371-381, 2002.
- Delcourt, D. C., T. E. Moore, S. Orsini, A. Millilo, and J.-A. Sauvaud, Centrifugal Acceleration of Ions Near Mercury, *Geophys. Res. Lett.*, 29(12), p.32-1, 2002.

- Delcourt, D. C., S. Grimald, F. Leblanc, J.-J. Berthelier, A. Millilo, A. Mura, S. Orsini, and T. E. Moore, A Quantitative Model of the Planetary Na⁺ Contribution to Mercury's Magnetosphere, *Ann. Geophys.*, in press, 2003.
- DelloRusso, N., M. A. DiSanti, K. Magee-Sauer, E. L. Gibb, and M. J. Mumma, Production of C₂H₆ and H₂O in Comet 2002 C1 Ikeya-Zhang on UT 2002 April 13.7-13.9, in *Asteroids, Comets, and Meteors*, ESA SP-XX, ESTEK:Noordwijk, The Netherlands, in press, 2002.
- DelloRusso, N., M. J. Mumma, M. A. DiSanti, and K. Magee-Sauer, Production of Ethane and Water in Comet Hyakutake, *J. Geophys. Res. (Planets)*, 107 (E11), 5095, doi:10.1029/2002JE001838, 2002.
- DiSanti, M. A., M. J. Mumma, N. DelloRusso, and K. Magee-Sauer, Carbon Monoxide Production and Excitation in Comet C/1995 O1 (Hale-Bopp): Isolation of Native and Distributed Sources, *Icarus*, 153: 361-390.
- DiSanti, M. A., M. J. Mumma, N. DelloRusso, and K. Magee-Sauer, Carbon Monoxide in Comet Hyakutake, *J. Geophys. Res.*, in press. 2002.
- DiSanti, M. A., N. DelloRusso, K. Magee-Sauer, E. L. Gibb, D. C. Reuter, and M. J. Mumma, CO, H₂CO, and CH₃OH in Comet Ikeya-Zhang, in *Asteroids, Comets, and Meteors*, ESA SP-500, ESTEK:Noordwijk, The Netherlands, pp. 571-574, 2002.
- DiSanti, M. A., M. J. Mumma, N. DelloRusso, and K. Magee-Sauer, Carbon Monoxide in Comet Hyakutake, *J. Geophys. Res. (Planets)* 108 (E6), 5061, doi:10.1029/2002JE001961, 2003.
- Dorelli, J. C., Effects of Hall Electric Fields on the Saturation of Forced Magnetic Field Line Merging, *Phys. Plasmas*, 10, 3309, 2003.
- Dubinin, E., A. Skalsky, P. Song, S. Savin, J. U. Kozyra, T. E. Moore, C. T. Russell, M. O. Chandler, A. Fedorov, L. Avannov, J.-A. Savaud, and R. H. W. Friedel, POLAR-INTERBALL Coordinated Observations of Plasma Characteristics in the Regions of the Northern and Southern Distant Cusps, *J. Geophys. Res.*, 107(A5), 10.1029/2001JA900068, 2002.
- Dworkin, J. P., J. S. Gillette, M. P. Bernstein, S. A. Sandford, L. J. Allamandola, J. E. Elsila, D. R. McGlothli, and R. N. Zare, An Evolutionary Connection Between Interstellar Ices and IDPs. Clues from Mass Spectroscopy Measurements of Laboratory Simulations, *Adv. Space Res.*, in press, 2003.
- Dworkin, J. P., A. Lazcano and S. L. Miller, The Roads to and From the RNA World, *J. Theor. Bio.*, 222, 127-134, 2003.
- Eisen, Y., L. G. Evans, S. Floyd, C. Schlemm, R. Starr, and J. I. Trombka, Radiation Damage of Schottky CdTe Detectors Irradiated by 200 MeV Protons, *Nucl. Inst. and Meth. In. Phys. Res. A.*, in press, 2002.
- Eisen, Y., L. G. Evans, R. Starr, and J. I. Trombka, CdWO₄ Scintillator as a Compact Gamma Ray Spectrometer for Planetary Lander Missions, *Nucl. Inst. and Meth. In. Phys. Res. A.*, in press, 2002.
- Espenak, F. and J. Anderson, Annular and Total Solar Eclipses of 2003, *NASA Technical Publication*, 2002-211618, 2002.
- Espenak, F., Australia's 2002 Total Eclipse of the Sun, *Mercury*, 31, 2, 34-35, 2002.
- Espenak, F., 2004 and 2012 Transits of Venus, *Proc. for Scientific Frontiers in Research on Extrasolar Planets*, PASP, 2003.
- Espenak, F., Eclipses During 2004, *2003 Observer's Handbook of the Roy. Astron. Soc. Can.*, 2003.
- Espenak, F., The 2004 Transit of Venus, *2003 Observer's Handbook of the Roy. Astron. Soc. Can.*, 2003.
- Esper, J., S. Neeck, J. A. Slavin, J. Leitner, W. Wiscombe, and F. H. Bauer, Nano/Micro Satellite Constellations for Earth and Space Science, *Acta Astronautica*, 52, 785-791, 2003.
- Evans, L. G., R. C. Reedy, and W. V. Boynton, Effects of Solar Particles on the Mars Odyssey Gamma-Ray Spectrometer, *34th Annual Lunar and Planetary Science Conference*, March 17-21, League City, Texas, No. 1591, 2003.
- Fainberg, J. and V. A. Osherovich, Solar Wind Quasi-Invariant as a Heliospheric Index of Solar Activity, *Proc. 10th European Solar Physics Meeting: "Solar Variability: From Core to Outer Frontiers"*, ESA SP-508, P.43-45, 2002.
- Farrell, W. M. and M. D. Desch, Solar Proton Events and the Fair Weather Electric Field at Ground, *Geophys. Res. Lett.*, 10.129/2001GL013908, 2002.
- Farrell, W. M., M. D. Desch, M. L. Kaiser, and K. Goetz, The Dominance of Electron Plasma Waves Near a Reconnection X-line Region, *Geophys. Res. Lett.*, in press, 2002.
- Farrell, W. M., R. J. Fitzenreiter, M. L. Kaiser, K. Goetz, M. Maksimovic, and M. J. Reiner, Continuum Emission and Broadband Electrostatic Noise at the Low Latitude Boundary Layer: A Diagnostic of Boundary Layer Dynamics, *Geophys. Res. Lett.*, 10.1029/2000GL012799, 2002.
- Farrell, W. M., R. A. Goldberg, M. D. Desch, J. G. Houser, J. D. Mitchell, C. L. Croskey, R. J. Blakeslee, D. M. Mach, and J. C. Bailey ACES: A Unique Platform for Electrodynamics Studies of Upward Currents into the Middle Atmosphere, *Proc. of the 12th International Conference on Atmospheric Electricity*, Versailles, France, 9/13 June, 2003.
- Farrugia, C. J., M. Popecki, E. Mobius, V. K. Jordanova, M. I. Desai, R. J. Fitzenreiter, K. W. Ogilvie, H. Matsui, S. Lepri, T. Zurbuchen, G. M. Mason, G. R. Lawrence, L. F. Burlaga, R. P. Lepping, J. R. Dwyer, and D. McComas, Wind and ACE Observations During the Great Flow of 1-4 May 1998: Relation to Solar Activity and

- Implications for the Magnetosphere, *J. Geophys. Res.*, 107(A9), No.-1240, 2002.
- Fast, K., T. Kostiuk, P. Romani, F. Espenak, T. Hewagama, A. Betz, R. Boreiko, and T. Livengood, Temporal Behavior of Stratospheric Ammonia Abundance and Temperature Following the SL9 Impacts, *Icarus*, 156, 485-497, 2002.
- Fast, K. E., T. Kostiuk, G. Sonnabend, T. Livengood, F. Espenak, J. Annen, M. F. A'Hearn and T. Hewagama, Peeking Through the Picket Fence: Observing Mars Ozone from the Earth, *AAS/Division for Planetary Sciences Meeting*, 35, 14.06, 2003.
- Filippov, B. P., N. Gopalswamy, and A. V. Lozhechkin, Motion of an Eruptive Prominence in the Solar Corona, *Astron. Rep.*, 46, 417, 2002.
- Fitzenreiter, R. J., K. W. Ogilvie, S. D. Bale, and A. F. Viñas, Modification of the Solar Wind Electron Velocity Distribution at Interplanetary Shocks, *J. Geophys. Res.*, in press, 2003.
- Fok, M.-C., T. E. Moore, G. R. Wilson, J. D. Perez, X. Zhang, P. Cson Brandt, D. G. Mitchell, E. C. Roelof, J.-M. Jahn, C. J. Pollock, and R. A. Wolf, Global ENA IMAGE Simulations, *Space Sci. Rev.*, in press, 2003.
- Fok, M.-C., et al., Global ENA IMAGE Simulations, *Space Sci. Rev.*, Special Issue, in press, 2003.
- Fok, M.-C., T. E. Moore, M. R. Collier, T. Tanaka, Neutral Atom Imaging of Solar Wind Interaction with the Earth and Venus, *J. Geophys. Res.*, in review, 2003.
- Forman, M. and L. F. Burlaga, Exploring the Castaing Distribution Function to Study Intermittence in the Solar Wind at 11 in June 2000, in *Solar Wind X*, Pisa, Italy, 2002.
- Fraser, B. J., J. L. Horwitz, and J. A. Slavin, Heavy Ion Mass Loading of the Geomagnetic Field Near the Plasmapause and ULF Wave Implications, *Geophys. Res. Lett.*, in press, 2003.
- Frey, H. U., T. J. Immel, G. Lu, J. Bonnell, S. A. Fuselier, S. B. Mende, B. Hubert, N. Ostgaard, and G. Le, Properties of Localized, High Latitude, Dayside Aurora, *J. Geophys. Res.*, 108(A4), 8008, doi:10.1029/2002JA009332, 2003.
- Frey, H. U., et al., Summary of Quantitative Interpretation of IMAGE Far Ultraviolet Aurorae Data, *Space Sci. Rev.*, Special Issue, in press, 2003.
- Fung, S. F., R. F. Benson, J. L. Green, B. W. Reinisch, D. M. Haines, I. A. Galkin, J.-L. Bougeret, R. Manning, P. H. Reiff, D. L. Carpenter, D. L. Gallagher, and W. W. L. Taylor, Observations of Magnetospheric Plasmas by the Radio Plasma Imager (RPI) on the IMAGE Mission, *Adv. Space Res.*, 30(10), 2259-2266, 2002.
- Fung, S. F., R. F. Benson, D. L. Carpenter, J. L. Green, V. Jayanti, I. A. Galkan, and B. W. Reinisch, Guided Echoes in the Magnetosphere: Observations by Radio Plasma Imager on IMAGE, *Geophys. Res. Lett.*, 3(11), 1589, doi:10.1029/2002GL016531, 2003.
- Fuselier, S. A., et al., Cusp Dynamics and Ionospheric Outflow, *Space Sci. Rev.*, in press, 2003.
- Fuselier, S. A., H. L. Collin, A. G. Ghielmetti, S. E. Claffin, T. E. Moore, M. R. Collier, H. Frey, and S. B. Mende, Localized Ion Outflow in Response to a Solar Wind Pressure Pulse, *J. Geophys. Res.*, 107(A8), SMP 26-1- SMP 26-9, 2001JA000297, 2002.
- Galkin, I., B. Reinisch, X. Huang, R. Benson, and S. Fung, Automated Diagnostics for Resonance Signature Recognition in RPI Plasmagrams, *Radio Sci.*, submitted, 2003.
- Georgiev, G., D. A. Glenar and J. J. Hillman, Spectral Characterization of Acousto-optic Filters Used in Imaging Spectroscopy, *Appl. Optics*, 41, 209-217, 2002.
- Gibb, E. L., M. J. Mumma, M. A. DiSanti, N. DelloRusso, and K. Magee-Sauer, An Infrared Search for HDO in Comets, in *Asteroids, Comets, and Meteors*, ESA SP-500, ESTEK:Noordwijk, The Netherlands, pp. 705-708, 2002.
- Gibb, E. L., M. J. Mumma, N. DelloRusso, M. A. DiSanti, and K. Magee-Sauer, Methane in Oort cloud Comets, *Icarus*, 165, 391-406, 2003.
- Gjerloev, J. W. and R. A. Hoffman, Currents in Auroral Substorms, *J. Geophys. Res.*, August 3, 2002.
- Gjerloev, J. W. and R. A. Hoffman, Implications of Ionospheric Substorm Electrodynamics Model, *Substorms-6*, accepted, 2002.
- Glenar D. A., R. E. Samuelson, J. C. Pearl, G. L. Bjoraker, and D. Blaney, Spectral Imaging of Martian Water Ice Clouds and their Diurnal Behavior During the 1999 Aphelion Season (Ls=130o), *Icarus*, 161, 297-318, 2003.
- Goldberg, R. A., D. C. Fritts, B. P. Williams, F. J. Schmidlin, C. L. Croskey, J. D. Mitchell, F. J. Lübken, M. Rapp, W. Singer, R. Latteck, T. A. Blix, M. Friedrih, S. Kirkwood, N. Mitchell, and K. Fricke, The MaCWAVER Program to Study Gravity Wave Forcing of the Polar Mesosphere during Summer and Winter, *Proc. of the 16th ESA Symposium on European Rocket and Balloon Programmes and Related Research*, 2/5 June 2003, St. Gallen, Switzerland, in press, 2003.
- Goldstein, M. L., D. A. Roberts, A. Deane, The Effect of Microstreams on Alfvénic Fluctuations in the Solar Wind, *Proc. of Solar Wind 10*, in press, 2003.
- González-Esparza, J. A., A. Lara, E. Perez-Tijerina, A. Santillan, and N. Gopalswamy, A Numerical Study on the Acceleration and Transit Time of Coronal Mass Ejections in the Interplanetary Medium, *J. Geophys. Res.*, 108, SSH9, 2003.
- Gopalswamy, N. and M. L. Kaiser, Solar Eruptions and Long Wavelength Radio Bursts: The 1997 May 12 Event, *Adv. Space Res.*, 29, 307, 2002.
- Gopalswamy, N., Space Weather Study Using Combined Coronagraphic and In-situ Observations, in *Space Weather Study Using Multipoint Techniques*, COSPAR

- Colloquia Series*, Vol. 12, edited by L.-H. Lyu, p. 39, 2002.
- Gopalswamy, N., Coronal Mass Ejections and Their Geospace Consequences, in *Silver Jubilee Symposium of the Udaipur Solar Observatory*, in press, 2002.
- Gopalswamy, N., Relation Between CME's and ICMEs, in *Proc. COSPAR Colloquium on Solar-terrestrial Magnetic Activity and Space Environment*, COSPAR Colloquia Series, 14, ed. By H. N. Wang and R. L. Xu, p. 157, 2002.
- Gopalswamy, N., S. Yashiro, G. Michalek, M. L. Kaiser, and R. A. Howard, Statistical Properties of Radio-rich Coronal Mass Ejections, in *Proc. COSPAR Colloquium on Solar-terrestrial Magnetic Activity and Space Environment*, Beijing, China, COSPAR Colloquia Series, 14, ed. By H. N. Wang and R. L. Xu, p. 173, 2002.
- Gopalswamy, N., S. Yashiro, G. Michalek, M. L. Kaiser, R. A. Howard, D. V. Reames, R. Leske, and T. von Roseninge, Interacting Coronal Mass Ejections and Solar Energetic Particles, *Astrophys. J.*, 572, L103, 2002.
- Gopalswamy, N., Coronal Mass Ejections: Initiation and Detection, *Adv. Space Res.*, 31(4), 869, 2003.
- Gopalswamy, N., Solar and Geospace Connections of Energetic Particle Events, *Geophys. Res. Lett.*, Volume 30, Issue 12, pp. SEP 1-1, CiteID 8013, DOI 10.1029/2003GL017277, 2003.
- Gopalswamy, N., Coronal Mass Ejections and Their Geospace Consequences, in *Probing the Sun with High Resolution*, eds. S. C. Tripathy, and P. Venkatakrishnan, Narosa Publishing House, New Delhi, p. 129, 2003.
- Gopalswamy, N., Interplanetary Radio Bursts, in *Solar and Space Weather Radiophysics*, ed. by D. E. Gary and C. O. Keller, Kluwer ASSL Volume, in press, 2003.
- Gopalswamy, N., A. Lara, S. Yashiro, S. Nunes, and R. A. Howard, Coronal Mass Ejection Activity During Solar Cycle 23, *Proceeding of Solar Variability as an input to the Earth's Environment*, ESA-SP, in press, 2003.
- Gopalswamy, N., S. Yashiro, G. Stenborg, and R. Howard, Coronal and Interplanetary Environment of Large Solar Energetic Particle Events, *Proceeding of 28th International Cosmic Ray Conference*, p. 3549, 2003.
- Gopalswamy, N., M. Shimojo, W. Lu, S. Yashiro, K. Shibasaki, and R. A. Howard, On Coronal Streamer Changes, *Adv. Space Res.*, in press, 2003.
- Gopalswamy, N., S. Yashiro, A. Lara, M. L. Kaiser, B. J. Thompson, P. T. Gallagher, and R. A. Howard, Large Solar Energetic Particle Events of Cycle 23: A Global View, *Geophys. Res. Lett.*, 30(12), pp. SEP 3-1, CiteID 8015, DOI 10.1029/2002GL016435, 2003.
- Gopalswamy, N., M. Shimojo, W. Lu, S. Yashiro, K. Shibasaki, and R. A. Howard, Prominence Eruptions and Coronal Mass Ejection: A Statistical Study Using Microwave Observations, *Astrophys. J.*, 586, 562, 2003.
- Gopalswamy, N., S. Nunes, S. Yashiro, and R. A. Howard, Variability of Solar Eruptions during cycle 23, *Adv. Space Res.*, in press, 2003.
- Gopalswamy, N., S. Yashiro, M. L. Kaiser, and R. A. Howard, Coronal Mass Ejection and Particle Acceleration During the 2001 April 14-15 Events, *Adv. Space Res.*, in press, 2003.
- Grebowsky, J. M., Equatorial F-Region Ion Composition Morphology from Satellite Measurements, *Adv. Space Res.*, 31, 681-686, 2003.
- Grebowsky, J. M., J. Moses, and W. D. Pesnell, Meteoric Material - an Important Component of Planetary Atmospheres, in *Comparative Aeronomy*, ed. M. Mendillo et al., AGU, Washington, D.C., 235, 2002.
- Grebowsky, J. M. and R. P. Buchanan, Ongoing Evolution of the Geospace Electrodynamical Connections Mission, IAF Paper Number IAA-02-IAA.11.1.05, *International Astronautical Federation*, Paris, France, 2002.
- Grebowsky, J. M., D. H. Crider, D. S. Intriligator, R. E. Hartle, and M. H. Acuña, Venus/Mars Pickup Ions and Ionosheath Wave Structures, *Adv. Space Res.*, in press, 2003.
- Green, J. L. and B. W. Reinisch, An Overview of Results from the RPI on IMAGE, *Space Sci. Rev.*, in press, 2003.
- Gudipati, M. S., J. P. Dworkin, X. D. F. Chillier and L. J. Allamandola, Luminescence from VUV Irradiated Cosmic Ice Analogs and Residues, *Astrophys. J.*, 583, 514-523, 2003.
- Gurnett, D. A., W. S. Kurth, G. B. Hospodarsky, A. M. Persoon, P. Zarka, A. Lecacheux, S. J. Bolton, M. D. Desch, W. M. Farrell, M. L. Kaiser, H. P. Ladreiter, H. O. Rucker, P. Galopeau, P. Loran, D. T. Young, W. R. Pryor, and M. K. Dougherty, Control of Jupiter's Radio Emission and Aurorae by the Solar Wind, *Nature*, 415, 985, 2002.
- Hess, R. H. and R. J. MacDowall, Scattering of Interplanetary Radio Waves at Kilometric Wavelengths, *J. Geophys. Res.*, 108, A8, 1313, doi: 10.1029/2002JA009783, 2003.
- Hesse, M., M. Kuznetsova, and M. Hoshino, The Structure of the Dissipation Region for Component Reconnection, *Geophys. Res. Lett.*, 29, 1563, 2002.
- Hesse, M., and J. Birn, On the Cessation of Magnetic Reconnection, *Annal. Geophys.*, in press, 2003.
- Hewagama, T., R. B. Barclay, T. C. Chen, D. Deming, C. Goukenleuque, M. A. Greenhouse, R. Henry, M. Jacobson, B. Mott, S. Satyapal, and D. S. Schwinger, Spectral Contrast Enhancement Techniques for Extrasolar Planet Imaging, *Proceedings of the SPIE*, ed. A. B. Schultz, 2003.
- Hill, H. G. M. and J. A. Nuth, The Catalytic Capability of Cosmic Dust: Implications for Prebiotic Chemistry in the Solar Nebula and Other Protoplanetary Systems, *Astrobiology*, 3, 291 - 304, 2003.

- Hinson, D. P., R. J. Wilson, M. D. Smith, and B. J. Conrath, Measurements and Simulations of Stationary Waves in the Southern Hemisphere of Mars, *J. Geophys. Res.*, in press, 2002.
- Hinson, D. P., R. J. Wilson, M. D. Smith, and B. J. Conrath, Stationary Planetary Waves in the Atmosphere of Mars During Southern Winter, *J. Geophys. Res.*, 108, doi:10.1029/2002JE001949, 2003.
- Hnat, B., S. C. Chapman, G. Rowlands, N. M. Watkins, and W. M. Farrell, Finite Size Scaling in the Solar Wind Magnetic Field Energy Density as Seen by Wind, *Geophys. Res. Lett.*, 10.129/2001GL014587, 2002.
- Huang, C.-S., G. D. Reeves, J. E. Borovsky, R. M. Skoug, Z. Y. Pu, and G. Le, Periodic Magnetospheric Substorms and Their Relationship with Solar Wind Variations, *J. Geophys. Res.*, 108(A6), 1255, doi:10.1029/2002JA009704, 2003.
- Huang, X., B. W. Reinisch, P. Song, I. A. Galkin, G. Cheney, J. L. Green, R. F. Benson, J. Tu and J. Horwitz, Conjugate Asymmetry in the Plasmaspheric Density Distributions at Solstice - RPI Case Studies, *Proc. of the Ionospheric Effects Symposium*, May 7-9, 2002, Alexandria, VA, 2002.
- Huang, X., B. W. Reinisch, D. Bilitza, and R. F. Benson, Electron Density Profiles of the Topside Ionosphere, *Ann. Geophys.*, 45, 125, 2002.
- Huang, C.-S., J. C. Foster, G. D. Reeves, G. Le, H. U. Frey, C. J. Pollock, Periodic Magnetospheric Substorms: Multiple Space-based and Ground-based Instrumental Observations, *J. Geophys. Res.*, in press, 2003.
- Hudson, R. L. and M. H. Moore, The N₃ Radical as a Discriminator Between Ion-irradiated and UV-photolyzed Astronomical Ices, *Astrophys. J.*, 568, 1095-1099, 2002.
- Hudson, R. L. and M. H. Moore, Solid-Phase Formation of Interstellar Vinyl Alcohol., *Ap. J. Lett.*, 586, L107-L110, 2003.
- Hurley, K., T. Cline, E. Mazets, S. Golenetskii, J. I. Trombka, T. McClanahan, R. Starr, J. Goldsten, C. Kouveliotou, J. Kommers, W. Lewin, and B. Stern, The Interplanetary Network Supplement to the Stern and Kommers Catalogs of Untriggered BATSE Gamma-Ray Bursts, *Am. Astron. Soc., 201st AAS Meeting*, Bulletin of the American Astronomical Society, Vol. 34, p.1219, 2002.
- Ingersoll, A. P., T. E. Dowling, P. J. Gierasch, G. S. Orton, P. L. Read, A. Sanchez-Lavega, A. P. Showman, A. A. Simon-Miller, and A. R. Vasavada, Dynamics of Jupiter's Atmosphere, in *Jupiter: The Planet, Satellites, and Magnetosphere*, edited by F. Bagenal, W. McKinnon, and T.E. Dowling, Cambridge University Press, submitted.
- Jones, H., S. Aslam, and B. Lakew, Characterization and Modeling of Excess Noise in High Tc Thin Film Bolometers, *Proc. International Workshop on Thermal Detectors - TDW03*, Washington DC, USA, in press.
- Kawano, H., G. Le, C. T. Russell, G. Rostoker, M. J. Brittner, and G. K. Parks, Substorm-time Magnetic Field Perturbations in the Polar Magnetosphere: POLAR Observations, *Earth Planets Space*, 54, 963-971, 2002.
- Keith, W. R., J. D. Winningham, A. N. Fazakerley, H. Rème, M. L. Goldstein, T. A. Fritz, and N. Cornilleau-Wehrin, Observations of a Unique Cusp Signature at Low and Mid Altitudes, *Surveys in Geophysics*, in press, 2003.
- Keller, J. W., Optimization Code for an Electrostatic Mirror Charged-particle Optical System, *Meas. Sci. Technol.*, 14, N64, 2003.
- Keller, J. W., M. A. Coplan, J. E. Lorenz, and K. W. Ogilvie, New Concept for the Measurement of Energetic Neutral Atom Composition and the Imaging of Their Sources, *AIP Conf. Proc.*, R.F. Wimmer-Schweingruber Ed., 598, 291, 2002.
- Keller, K. A., M. Hesse, M. Kuznetsova, L. Rastätter, T. Moretto, T. I. Gombosi, and D. L. DeZeeuw, Global MHD Modeling of the Impact of a Solar Wind Pressure Change, *J. Geophys. Res.*, 107, 1126, 2002.
- Khan, H., M. R. Collier, and T. E. Moore, Detailed Analysis of an Ionospheric Outflow Event Observed by IMAGE During Solar Wind Pressure Variations, *J. Geophys. Res.*, in press, 2003.
- Khanna, R. K., M. S. Lowenthal, H. L. Ammon, and M. H. Moore, Molecular Structure and IR Spectrum of Solid Amino Formate (HCO₂NH₂): Relevance to Interstellar Ices, *Astrophys. J. Supp.*, 140, 457, 2002.
- Khare, B., M. Meyyappan, M. H. Moore, P. Hilhite, H. Imanaka, and B. Chen, Proton Irradiation of Carbon Nanotubes. *Nano Letters*, American Chemical Society, accepted, 2003.
- Khazanov, G. V., M. W. Liemohn, T. S. Newman, M.-C. Fok, and R. W. Spiro, Self-consistent Magnetosphere-ionosphere Coupling: Theoretical Studies, *J. Geophys. Res.*, 108(A3), 1122, doi:10.1029/2002JA009624, 2003.
- Kirkwood, S., E. Belova, P. Dalin, K. H. Fricke, U. Blum, F. Schmidlin, and R. A. Goldberg, Polar Mesospheric Winter Echoes during MaCWAVE, *Proceedings of the 16th ESA Symposium on European Rocket and Balloon Programmes and Related Research*, St. Gallen, Switzerland, in press, 2003.
- Klaasen, K. P., H. H. Breneman, A. A. Simon-Miller, D. Banfield, and G. C. Levanas, Final Calibration of the Galileo Solid-State Imaging System in Jupiter Orbit, *Optical Engineering*, accepted.
- Kletetschka, G., N. F. Ness, P. J. Wasilewski, J. E. P. Connerney, and M. H. Acuña, Possible Mineral Sources of Magnetic Anomalies on Mars, *The Leading Edge*, 22(8), 766-768, 2003.
- Kletetschka, G., T. Kohout, and P. J. Wasilewski, Magnetic Remanence in Murchison Meteorite," *Meteoritics & Planetary Science*, 38(3), 399-406, 2003.

- Kletetschka, G., V. Zila, and P. J. Wasilewski, Magnetic Anomalies on the Tree Trunks, *Studia geophysica et geodetica*, 47(2), 371-379, 2003.
- Kletetschka, G., P. J. Wasilewski, and P. T. Taylor, The Role of Hematite - ilmenite Solid Solution in the Production of Magnetic Anomalies in Ground and Satellite Based Data, *Tectonophysics*, 347 (1-3), 166-177, 2002.
- Kletetschka, G. and P. J. Wasilewski, Grain size limit for SD hematite, *Physics of the Earth and Planetary Interiors*, (129(1-2), 173-179, 2002.
- Klimas, A. J., V. Uritsky, D. Vassiliadis, and D. N. Baker, Reconnection and Scale-free Avalanching in a Driven Current-sheet Model, *J. Geophys. Res.*, in press, 2003.
- Korotova, G. I., D. G. Sibeck, H. J. Singer, and T. J. Rosenberg, Tracking Transient Events Through Geosynchronous Orbit and in the High-latitude Ionosphere, *J. Geophys. Res.*, 107, 10.1029/2002JA009477, 2002.
- Korth, H., B. J. Anderson, R. L. McNutt, Jr., M. H. Acuña, J. A. Slavin, N. A. Tsyganenko, and S. C. Solomon, Determination of the Properties of Mercury's Magnetic Field by the MESSENGER Mission, *Planet. Sp. Sci.*, in press, 2003.
- Kossacki, K. J., W. J. Markiewicz, and M. D. Smith, Surface Temperature of Martian Regolith with Polygonal Features: Influence of the Subsurface Water Ice, *Planet. Space Sci.*, 51, 569-580, 2003.
- Kostiuk, T., K. Fast, T. A. Livengood, F. Schmüling, T. Hewagama, D. Buhl, P. Romani and H. U. Käuff, Ethane on Saturn: Spatial and Temporal Variation, *AAS/Division for Planetary Sciences Meeting*, 35, 50.05, 2003.
- Kotova, G., M. Verigin, G. Zastenker, N. Nikolayeva, B. Smolkin, J. Slavin, A. Szabo, J. Meka, Z. Nemechek, and J. Safrankova, Bow Shock Observations by Prognoz 11: Analysis and Model Comparison, *Adv. Space Sci.*, in press, 2003.
- Kozyra, J. U. and M. W. Liemohn, Ring Current Energy Input and Decay, *Space Science Reviews*, Special Issue, in press, 2003.
- Kudela, K., V. N. Lutsenko, D. G. Sibeck, and M. Slivka, Energetic Ions and Wlectrons within the Magnetosheath and Upstream of the Bow Shock: Interball-1 Overview , *Adv. Space Res.*, 30, 1685-1692, 2003.
- Kudela, K., V. N. Lutsenko, D. G. Sibeck, M. Slivka, T. V. Gretchko, and E. T. Sarris, High Energy Particle Dispersion Events Observed by Interball-1 and -2, *Adv. Space Res.*, 30, 2849-2854, 2003.
- Kurth, W. S., D. A. Gurnett, G. B. Hospodarsky, W. M. Farrell, A. Roux, M. K. Dougherty, S. P. Joy, M. G. Kivelson, R. J. Walker, F. J. Cray, and C. J. Alexander, The Dusk Flank of Jupiter's Magnetosphere, *Nature*, 415, 991, 2002.
- Krymskii, A. M., T. K. Breus, N. F. Ness, M. H. Acuña, J. E. P. Connerney, D. H. Crider, D. L. Mitchell, and S. J. Bauer, Structure of the Magnetic Field Fluxes Connected with Crustal Magnetization and Topside Ionosphere at Mars, *J. Geophys. Res.*, 107, (A9), 1245, doi:10.1029/2001JA000239, 2002.
- Laakso, H., R. Pfaff, and P. Janhunen, Polar Observations of Electron Density Distribution in the Earth's Magnetosphere: 2. Density Profiles, *Ann. Geophys.*, in press, 2002.
- Laakso, H., R. Pfaff, P. Janhunen, Polar Observations of Electron Density Distribution in the Earth's Magnetosphere: 1, *Statistical Results*, *Ann. Geophys.*, in press, 2002.
- Lakew, B., and J. C. Brasunas, Recent Advances in High and Mid Temperature Superconducting Thin Films for Infrared Sensor Applications, Proc. International Workshop on Thermal Detectors - TDW03, Washington DC, USA, in press (Invited paper), 2003.
- Lara, A., J. A. Gonzalez-Esparza, and N. Gopalswamy, Characteristics of Coronal Mass Ejections in the Near Sun Interplanetary Space, in press, 2002.
- Lara, A., N. Gopalswamy, S. Nunes, G. Muñoz, S. Yashiro, A Statistical Study of CMEs Associated with Metric Type II Bursts, *Geophys. Res. Lett.*, 2003, 30, September 4, 2003.
- Le, G., G. Lu, R. J. Strangeway, and R. F. Pfaff, Jr., Strong IMF By-related Plasma Convection in the Ionosphere and Cusp Field-aligned Currents Under Northward IMF Conditions, *J. Geophys. Res.*, in press, 2002.
- Le, G., G. Lu, R. J. Strangeway, and R. F. Pfaff Jr., Strong Interplanetary Magnetic Field By -related Plasma Convection in the Ionosphere and Cusp Field-aligned Currents Under Northward Interplanetary Magnetic Field Conditions, *J. Geophys. Res.*, 107(A12), 1477, doi:10.1029/2001JA007546, 2002.
- Le, G., C.-S. Huang, R. F. Pfaff, S.-Y. Su, H.-C. Yeh, R. A. Heelis, F. J. Rich, and M. Hairston, Plasma Density Enhancements Associated with Equatorial Spread F: ROCSAT-1 and DMSP Observations, *J. Geophys. Res.*, 108(A8), 1318, doi:10.1029/2002JA009592, 2003.
- Le, G., C. T. Russell, and K. Takahashi, Morphology of the Ring Current Derived from In-situ Magnetic Field Measurements, *Ann. Geophys.*, in press, 2003.
- Lemon, C., F. Toffoletto, M. Hesse, and J. Birn, Computing Magnetospheric Force Equilibria Using MHD, *J. Geophys. Res.*, 108, 1237, 2003.
- Lepping, R. P., D. Berdichevsky, A. Szabo, A. J. Lazarus, and B. J. Thompson, Upstream Shocks and Interplanetary Magnetic Cloud Speed and Expansion: Sun, Wind, and Earth Observations, Space Weather Study Using Multipoint Techniques, *Proceedings of COSPAR Colloquium Series*, Vol. 12, ed. L.-H. Lyu, Pergamon Press, New York, 87, 2002.
- Lepping, R. P., D. Berdichevsky, A. Szabo, C. Arqueros, and A. J. Lazarus, Profile of a Generic Magnetic Cloud

- at 1 AU for the Quiet Solar Phase: Wind Observations, *Solar Phys.*, 212, 425-444, 2003a.
- Lepping, R. P., D. B. Berdichevsky, and C.-C. Wu, Sun-Earth Electrodynamics: The Solar Wind Connection, Research Signpost, *Recent Res. Devel. in Astrophys.*, 1(2003): 139 - 171 ISBN: 81 - 271-0004-8, 2003b.
- Lepping, R. P., C.-C. Wu, and K. McClernan, The Two Dimensional Curvature of Large-Angle Interplanetary MHD Discontinuity Surfaces: IMP-8 and WIND Observations, *J. Geophys. Res.*, in press, 2003c.
- Lepping, R. P., D. Berdichevsky, and T. Ferguson, Estimated Errors in Magnetic Cloud Model Fit-Parameters with Force Free Cylindrically Symmetric Assumptions, *J. Geophys. Res.*, in press, 2003d.
- Lepping, R. P., W. H. Mish, E. C. Sittler and S. A. Curtis, Analysis of Waves in Saturn's Dayside Magnetosphere: Voyager 1 Observations, *J. Geophys. Res.*, in preparation, 2003.
- Lin, N., P. J. Kellogg, R. J. MacDowall, D. J. McComas, A. Balogh, and R. J. Forsyth, Comparison of VLF Wave Activity in the Solar Wind During Solar Maximum and Minimum, Ulysses observations, *10th International Conference on Solar Wind*, Ed. M. Velli, AIP Conference Proceedings, in press, 2003.
- Lin, N., P. J. Kellogg, R. J. MacDowall, D. J. McComas, and A. Balogh, VLF Wave Activity in the Solar Wind and the Photoelectron Effect in the Electric Field Measurements: Ulysses Observations, *Geophys. Res. Lett.*, submitted, 2003.
- Liou, K., C.-I. Meng, P. T. Newell, C.-C. Wu, and R. P. Lepping, Do Interplanetary Shocks Really Trigger Substorm Expansion Phase Onsets?, *Proceedings of the ICS-6 Conference*, ed. R. M. Winglee, Seattle, Washington, March 25-29, 299-304, 2002.
- Liou, K., P. T. Newell, C.-I. Meng, C.-C. Wu, and R. P. Lepping, Investigation of External Triggering of Substorms with Polar Ultraviolet Imager Observations, *J. Geophys. Res.*, accepted, 2003.
- Livengood, T. A., T. Hewagama, T. Kostiuk, K. E. Fast, and J. J. Goldstein, Improved Determination of Ethane (C_2H_6) Abundance in Titan's Stratosphere, *Icarus*, 157, 249-253, 2002.
- Livengood, T. A., T. Kostiuk, K. E. Fast, J. N. Annen, G. Sonnabend and T. Hewagama, Meridional Mapping of Mesospheric Temperatures from CO_2 Emission Along the MGS Ground Track, *AAS/Division for Planetary Sciences Meeting*, 35, 03.04, 2003.
- Lu, G., S. W. H. Cowley, S. E. Milan, D. G. Sibeck, R. A. Greenwald, and T. Moretto, Solar Wind Effects on Ionospheric Convection: A Review, *J. Atmo. Terr. Phys.*, 64, 145-157, 2002.
- MacDowall R. J., N. Lin, and D. J. McComas, Heliospheric Langmuir Wave Observations from the Ulysses Spacecraft, *Adv. Spa. Res.*, in press, 2003.
- Magee-Sauer, K., M. J. Mumma, M. A. DiSanti, and N. DelloRusso, Hydrogen Cyanide in Comet Hyakutake *J. Geophys. Res. (Planets)*, 107 (E11), 5096, doi:10.129/2002JE001863, 2002.
- Magee-Sauer, K., N. DelloRusso, M. A. DiSanti, E. L. Gibb, and M. J. Mumma, Production of HCN and C_2H_2 in C/2002 C1 Ikeya-Zhang on UT 2002 April 13.8, in *Asteroids, Comets, and Meteors* ESA SP-500. ESTEK:Noordwijk, The Netherlands, pp. 549-552, 2002.
- Maguire, W. C., J. C. Pearl, M. D. Smith, B. J. Conrath, A. A. Kutepov, M. S. Kaelberer, E. Winter, and P. R. Christensen, Observations of High Altitude CO_2 Hot Bands in Mars By the Orbiting Thermal Emission Spectrometer, *J. Geophys. Res.*, 107(0), 10.1029/2001JE001516, 2002.
- McComas, D. J., N. A. Schwadron, F. J. Crary, H. A. Elliot, D. T. Young, J. T. Gosling, M. F. Thomsen, E. C. Sittler Jr., J.-J. Berthelier, K. Szego and A. J. Coates, The Interstellar Hydrogen Shadow: Observations of Interstellar Pickup Ions Beyond Jupiter, *J. Geophys. Res.*, submitted, 2003.
- Mende, S. B., et al., Global Imaging of Proton and Electron Aurorae in the Far Ultraviolet, *Space Science Reviews*, Special Issue, in press, 2003.
- Merka, J., A. Szabo, T. W. Narock, J. H. King, K. I. Paularena, and J. D. Richardson, A Comparison of IMP 8 Observed Bow Shock Positions with Model Predictions, *J. Geophys. Res.*, doi:10.1029/2002JA009384, 2003.
- Merka, J., A. Szabo, J. Safrankova and Z. Nemecek, Earth's Bow Shock and Magnetopause in the Case of a Field-aligned Upstream flow: Observations and Model Comparison, *J. Geophys. Res.*, doi:10.1029/2002JA009697, 2003.
- Mertens, C. J., F. J. Schmidlin, R. A. Goldberg, E. E. Remsburg, W. D. Pesnell, J. M. Russell III, M. G. Mlynczak, M. Lopez-Puertas, P. P. Wintersteiner, R. H. Picard, J. R. Winick, and L. L. Gordley, SABER Observations of Mesospheric Temperatures and Comparisons with Falling Sphere Measurements Taken during the 2002 Summer MaCWAVE Campaign, submitted to *Geophys. Res. Lett.*, 30, 2003.
- Michael, B. P., Lembit U. Lilleleht, and J. A. Nuth, Zinc Crystal Growth in Microgravity, *Ap. J.*, 590, 579 - 585, 2003.
- Michalek, G., N. Gopalswamy, and E. Chane, Arrival Time of Coronal Mass Ejections, *The 10th European Solar Physics Meeting*, September 2002, Prague, Czech Republic. Ed. A. Wilson. ESA SP-506, Vol. 1. p. 177, 2002.
- Michalek, G., N. Gopalswamy, and S. Yashiro, A New Possibility to Estimate the Width, Source Location and Velocity of Halo CMEs, *Proceedings of the SOHO 11 Symposium on From Solar Min to Max: Half a Solar Cycle with SOHO*, Davos, Switzerland, Edited by A. Wilson, ESA SP-508, p.453, 2002.

- Michalek, G., N. Gopalswamy, M. Reiner, S. Yashiro, M. L. Kaiser, and R. A. Howard, Estimation of Projection Effect of CMEs from the Onset Time of Shock-associated Type III Radio Burst, *Proc. of the SOHO 11 Symposium on From Solar Min to Max: Half a Solar Cycle with SOHO*, 11-15 March 2002, Davos, Switzerland. ed. A. Wilson, ESA SP-508, Noordwijk: ESA p. 449, 2002.
- Miller, J. A. and A. F. Viñas, A One-dimensional Electrostatic Vlasov Simulation, submitted to *Am. J. Phys.*, 2003.
- Mitchell, D. G., et al., Global Imaging of O+ from IMAGE/HENA, *Space Science Reviews*, Special Issue, in press, 2003.
- Moldwin, M., et al., Quantifying Global Plasmaspheric Images with in-situ Observations, *Space Science Reviews*, Special Issue, in press, 2003.
- Moon, Y.-J., G. S. Choe, H. Wang, Y. D. Park, N. Gopalswamy, G. Yang, and Y. Yashiro, A Statistical Study of Two Classes of Coronal Mass Ejections, *Astrophys. J.*, 581, 694, 2002.
- Moore, M. H., R. L. Hudson, and R. F. Ferrante, Radiation Products in Processed Ices Relevant to Edgeworth-Kuiper-Belt Objects. *Earth Moon and Planets*, (accepted), 2003.
- Moore, M. H., and R. L. Hudson, Infrared Study of Ion Irradiated N₂-Dominated Ices Relevant to Triton and Pluto: Formation of HCN and HNC. *Icarus*, 161, 486-500, 2003.
- Moore, T. E., M.-C. Fok, M. O. Chandler, and S. A. Fuselier, The Dayside Reconnection X-line, *J. Geophys. Res.*, 107(A10), p. SMP 26, 2002.
- Moore, T. E., et al., Heliosphere-Geosphere Interactions Using Low Energy, *Space Sci. Rev.*, in press, 2003.
- Moore, T. E., M. R. Collier, M. -C. Fok, S. A. Fuselier, H. Khan, W. Lennartsson, D. G. Simpson, G. R. Wilson, and M. O. Chandler, Heliosphere-geosphere Interactions Using Low Energy Neutral Atom Imaging, *Space Sci. Rev.*, in press, 2003.
- Moretto, T., M. Hesse, A. Yahnin, A. Ieda, D. Murr, and J. F. Watermann, Magnetospheric Signatures of an Ionospheric Traveling Convection Vortex Event, *J. Geophys. Res.*, 107, 1072, 2002.
- Morozhenko, V., T. Kostiuik, D. Buhl, T. Hewagama, T. A. Livengood, A. Kollyukh, and W. E. Blass, Infrared Heterodyne Spectroscopic Measurements of Ethylene and Isotopic Ethylene (¹³C¹²CH₄) Transitions Between 840cm⁻¹ and 980 cm⁻¹, *Journal of Quantitative Spectroscopy and Radiative Transfer*, 72,101-115, 2002.
- Morozhenko, V., T. Kostiuik, W. E. Blass, T. Hewagama, and T. A. Livengood, Self- and Nitrogen-Broadening of the ν_{10} 20_{11,10}←19_{10,9} Ethylene Transition at 927.01879 cm⁻¹, *Journal of Quantitative Spectroscopy and Radiative Transfer*, 72, 193-198, 2002.
- Moses, J. I., T. Fouchet, R. V. Yelle, A. J. Friedson, G. S. Orton, B. Bézard, P. Drossart, G. R. Gladstone, T. Kostiuik and, T. A. Livengood, The Stratosphere of Jupiter, in *Jupiter: Planet, Satellites & Magnetosphere*, ed. F. Bagenal, Cambridge, U.K.: Cambridge University Press, in press, 2003.
- Mott, D. B., R. B. Barclay, A. Bier, T. C. Chen, B. DiCamillo, D. Deming, M. A. Greenhouse, R. Henry, T. Hewagama, M. Jacobson, M. Quijada, S. Satyapal, and D. S. Schwinger, Micromachined Tunable Fabry-Perot Filters for Infrared Astronomy, *Proc. of the SPIE*, ed. M. Iye and A. F. M. Moorwood, 2003.
- Mumma, M. J., Chemical Diversity Among Comets: Implications for Delivery of Water and Prebiotic Organics to Early Earth, *Geochim. et Cosmochim.*, Acta 66 (No. S1):A534, 2002.
- Mumma, M. J., M. A. DiSanti, N. DelloRusso, K. Magee-Sauer, E. Gibb, and R. Novak, The Organic Volatile Composition of Oort-cloud Comets: Evidence for Chemical Diversity in the Giant-planets' Nebular Region, in *Asteroids, Comets, and Meteors*, ESA SP-500, ESTEK:Noordwijk, The Netherlands, 753-762, 2002.
- Mumma, M. J., M. A. DiSanti, N. DelloRusso, K. Magee-Sauer, E. Gibb, and R. Novak, Remote Infrared Observations of Parent Volatiles in Comets: A Window on the Early Solar System, *Adv. Sp. Res.*, 31 (12), 2563-2575, 2003.
- Narock, T. W., A. Szabo, and R. P. Lepping, Distributed Data Systems and OWL: A Space Science Example, *Proc. 2nd International Semantic Web Conference*, Florida, October, in press, 2003.
- Nesbitt, F. L., R. J. Cody, D. A. Dalton, V. Riffault, Y. Bedjanian, and G. Le Bras, Temperature Dependence of the Rate Constant for the Reaction F(²P) + Cl₂ → FCl at T = 180-360 K, *J. Phys. Chem. A*, submitted, 2003.
- Novak, R. E., M. J. Mumma, M. A. DiSanti, N. DelloRusso, and K. Magee-Sauer, Mapping of Ozone and Water in the Atmosphere of Mars near the 1997 Aphelion, *Icarus*, 158:14-23, 2002.
- Nsumei, P. A., X. Huang, B. W. Reinisch, P. Song, V. M. Vasyliunas, J. L. Green, S. F. Fung, R. F. Benson, and D. L. Gallagher, Electron density over the Northern Polar Region Deduced from IMAGE/RPI Sounding, *J. Geophys. Res.*, 108(A2), 1078, doi:10.1029/2002JA009616, 2003.
- Nuth, J. A., F. J. M. Rietmeijer, and H. G. M. Hill, Condensation Processes in Astrophysical Environments: The Composition and Structure of Cometary Grains, *Meteoritics and Planetary Science*, 37,1579 - 1590, 2002.
- Osherovich, V. A., J. Fainberg, A. F.-Viñas, and R. J. Fitzenreiter, Complexity of the 18 October 1995 Magnetic Cloud Observed by Wind and Multi-tube Magnetic Cloud Model, *Solar Wind 10*, in press, 2003.
- Osherovich, V. A., J. Fainberg, and C. J. Farrugia, Self-Similar Oscillations of Electrons in Cold Plasma

- with Constant Background for Cylindrical, Spherical and Plane Geometries, submitted *Phys. Rev. Lett.*, 2003.
- Osherovich, V. A. and J. Fainberg, Dependence of Frequency of Nonlinear Cold Plasma Cylindrical Oscillations on Electron Density, submitted *J. of Plasma Phys.*, 2003.
- Ostgaard, N., G. Germany, J. Stadsnes, and R. Vondrak, Energy Analysis of Substorms Based on Remote Sensing Techniques, Solar Wind Measurements and Geomagnetic Indices, *J. Geophys. Res.*, 107(A9), 1233, doi:10.1029/2001JA002002, 2002.
- Ostgaard, N., R. Vondrak, J. Gjerloev, and G. Germany, A Relation Between the Energy Deposition by Electron Precipitation and Geomagnetic Indices During Substorms, *J. Geophys. Res.*, 107(A9), 1246, doi:10.1029/2001JA002003, 2002.
- Ostgaard, N., D. Detrick, T. Rosenberg, R. Vondrak, H. Frey, S. Mende, S. Haland, and J. Stadsnes, High-latitude Dayside Energetic Precipitation and IMF Bz Rotations, *J. Geophys. Res.*, 108, No. A4, 8013, doi:10.1029/2002JA009350, 2003.
- Pesnell, W. D., J. M. Grebowsky, and A. L. Weisman, Watching Meteors on Triton, *Icarus*, in press, 2003.
- Pickett, J. S., S. W. Kahler, L.-J. Chen, R. L. Huff, O. Santolik, Y. Khotyaintsev, P. M. E. Décréau, D. Winningham, M. L. Goldstein, G. S. Lakhina, B. T. Tsurutani, B. Lavraud, D. A. Gurnett, N. Cornilleau-Wehrlin, M. André, A. Fazakerley, A. Balogh, H. Réme, Isolated Electrostatic Structures Observed in the Auroral Zone: The Cluster Multispacecraft Perspective *Nonlinear Processes in Geophysics*, submitted, 2003.
- Price, P. A., E. Berger, S. R. Kulkarni, S. G. Djorgovski, D. W. Fox, A. Mahabal, K. Hurley, J. S. Bloom, D. A. Frail, T. J. Galama, F. A. Harrison, G. Morrison, D. E. Reichart, S. A. Yost, R. Sari, T. S. Axelrod, T. Cline, S. Golenetskii, E. Mazets, B. P. Schmidt, J. I. Trombka, The Unusually Long Duration Gamma-Ray Burst GRB 000911: Discovery of the Afterglow and Host Galaxy, *Astrophys. J.*, 573 (1), pp. 85-91. 2002.
- Pugel, D. E., B. Lakew, and S. Aslam, Fabrication of Monolithic Sapphire for HTS Bolometer Array Development, Proc. *International Workshop on Thermal Detectors - TDW03*, Washington DC, USA, in press.
- Pulkkinen, T. I., E. I. Tanskanen, M. Wiltberger, J. A. Slavin, T. Nagai, G. D. Reeves, L. A. Frank, and J. B. Sigwarth, Magnetotail Flows can Consume as much Solar Wind Flows as a Substorm, *J. Geophys. Res.*, 108(A8), 1326, doi:10.1029/2001JA009132, 2003.
- Pulkkinen, T. I., H. E. J. Koskinen, K. Kauristie, M. Palmroth, G. D. Reeves, E. Donovan, H. J. Singer, J. A. Slavin, C. T. Russell, and K. Yumoto, Storm-substorm Coupling: Signatures of Stormtime Substorms, *Proc. Galperin Conf.*, in press, 2003.
- Rastätter, L., M. Hesse, M. Kuznetsova, T. I. Gombosi, and D. L. DeZeeuw, Magnetic Field Topology During the July 14-16, 2000 Bastille Solar CME Event, *Geophys. Res. Lett.*, 29, 2002.
- Reedy, R. C., L. G. Evans, J. Brückner, K. J. Kim, and W. V. Boynton, Gamma Rays in a Spectrum from the Mars Odyssey Gamma-Ray Spectrometer, *34th Annual Lunar and Planetary Science Conference*, March 17-21, League City, Texas, No.1592, 2003.
- Reinisch, B., X. Huang, P. Song, I. Galkin, G. Khmyrov, R. Benson, S. Fung, and J. Green, Effects of Magnetostorms on the Plasmaspheric Density Distribution, *Proceedings of the Ionospheric Effects Symposium*, May 7-9, 2002, Alexandria, VA, 2002.
- Richardson, I. G., G. R. Lawrence, D. K. Haggerty, T. A. Kucera, A. Szabo, Are CME "Interactions" Really Important for Accelerating Major Solar Energetic Particle Events?, *Geophys. Res. Lett.*, 30, 12, doi:10.1029/2002GL016424, 2003.
- Richardson, J. D., K. I. Paularena, C. Wang, and L. F. Burlaga, The Life of a CME and the Development of a MIR: From the Sun to 58 AU, *J. Geophys. Res.*, 108, No. A5, doi:10.1029/2002JA009809, 2003.
- Richardson, L. J., D. Deming, G. Wiedemann, C. Goukenleuque, D. Steyert, J. Harrington, and L. W. Esposito, Infrared Observations during the Secondary Eclipse of HD 209458b. I. 3.6 Micron Occultation Spectroscopy Using the Very Large Telescope, *Astrophys. J.*, 584, 1053, 2003.
- Richardson, L. J., D. Deming, and S. Seager, Infrared Observations During the Secondary Eclipse of HD 209458 b II. Strong Limits on the Infrared Spectrum Near 2.2 Microns, *Astrophys. J.*, in press, 2003.
- Rietmeijer F. J. M. and J. A. Nuth III, Experimental Astromineralogy: Circumstellar Ferromagnesio-silica Dust in Analogs and Natural Samples, in *Dust in the Solar System and Other Planetary Systems*, COSPAR Colloquia Series, vol. 15 (S.F. Green, I.P. Williams, J.A.M. McDonnell and N. McBride, eds), pp. 333-342, 2003.
- Rietmeijer, F. J. M., J. A. Nuth, J. M. Karner, and S. L. Hallenbeck, Gas-to-Solid Condensation in a Mg-SiO₂-H₂-O₂ Vapor: Metastable Eutectics in the MgO - SiO₂ Phase Diagram, *J. Phys. Chem.*, Chem. Phys. 4, 546-551, 2002.
- Rietmeijer, F. J. M., S. L. Hallenbeck, J. A. Nuth, and J. M. Karner, Amorphous Magnesiosilicate Smokes Annealed in Vacuum: The Evolution of Magnesium Silicates in Circumstellar and Cometary Dust, *Icarus*, 146, 269, 2002.
- Roberts, D. A., M. L. Goldstein, A. Deane, Three-Dimensional MHD Simulation of Solar Wind Structure, *Proceedings of Solar Wind 10*, in press, 2003.
- Safrankova, J., Z. Nemecek, S. Dusik, D. G. Sibeck, and N. L. Borodkova, The Magnetopause Shape and Location: A Comparison of the Interball and Geotail Observations with Models, *Ann. Geophys. Res.*, 30, 301-309, 2002.

- Safrankova, J., L. Prech, Z. Nemecek, and D. Sibeck, The Structure of Hot Flow Anomalies in the Magnetosheath, *Adv. Space Res.*, 30, 2737-2744, 2002.
- Sales, G. S., X. Huang, B. Reinisch, I. Galkin, and R. Benson, Amplitude and Polarization of Field Aligned Propagating Radio Signals in the Plasmasphere Observed with RPI on IMAGE, *Ionospheric Effects Symposium*, May 7-9, 2002, Alexandria, VA, 2002.
- Sandel, B. R., et al., EUV Observations of the Structure and Dynamics of the Plasmasphere, *Space Science Reviews*, Special Issue, in press, 2003.
- Sanny, J. and D. G. Sibeck, FTE Occurrence Patterns at Geosynchronous Orbit, *J. Geophys. Res.*, in press, 2002.
- Sanny, J., J. A. Tapia, D. G. Sibeck, and M. B. Moldwin, Quiet Time Variability of the Geosynchronous Magnetic Field and Its Response to the Solar Wind, *J. Geophys. Res.*, 107, 1443, doi:10.1029/2002JA009448, 2002.
- Sharma, A., D. Baker, M. Grande, Y. Kamide, G. Lakhina, R. McPherron, G. Reeves, G. Rostoker, R. Vondrak, and L. Zelenyi, Storm-Substorm Relationship: Current Understanding and Outlook, *AGU Monograph on Storm-Substorm Relationships*, in press, 2003.
- Shue, J.-H., P. T. Newell, K. Liou, C.-I. Meng, Y. Kamide, and R. P. Lepping, Two-Component Auroras, *Geophys. Res. Lett.*, 29, DOI 10.1029/2002GL014657, pp. 17-1, 2002.
- Sibeck, D. G., T.-D. Phan, R. Lin, R. P. Lepping, and A. Szabo, Wind Observations of Foreshock Cavities: A Case Study, *J. Geophys. Res.*, 107, 10.1029/2001JA007539, 2002.
- Sibeck, D. G. and G. N. Zastenker, Plasma Processes in the Near-Earth Space: Interball and Beyond, *Adv. Space Res.*, 31, 1125-1480, 2003.
- Sibeck, D. G., N. B. Trivedi, E. Zesta, R. B. Decker, H. J. Singer, A. Szabo, H. Tachihara, and J. Watermann, Pressure-pulse Interaction with the Magnetosphere and Ionosphere, *J. Geophys. Res.*, 108, 10.1029/2002JA009675, 2003.
- Sigsbee, K., C. A. Cattell, D. Fairfield, K. Tsuruda, and S. Kokubun, Geotail Observations of Low-frequency Waves and High-speed Earthward Flows During Substorm Onsets in the Near Magnetotail from 10 to 13 RE, *J. Geophys. Res.*, 107(A7), 1141, doi:10.1029/2001JA000166, 2002.
- Simon-Miller, A. A. and N. J. Chanover, Planetary Astronomy: Recent Advances and Future Discoveries with Small Aperture Telescopes, *In Small Telescopes in the Era of Big Glass*, (T. Oswalt, Ed.), Kluwer Academic Press: New York, in press.
- Simon-Miller, A. A., P. J. Gierasch, R. F. Beebe, B. Conrath, F. M. Flasar, R. K. Achterberg, and the Cassini CIRS Team, New Observational Results Concerning Jupiter's Great Red Spot, *Icarus*, 158, 249-266, 2002.
- Simon-Miller, A. A. and N. J. Chanover, Planetary Astronomy: Recent Advances and Future Discoveries with Small Aperture Telescopes, in *The Future of Small Telescopes*, in the New Millennium 3. Science in the Shadow of Giants (T. Oswalt, Ed.). Kluwer Academic Press: New York, pp. 37-55, 2003.
- Sittler, E. C., Jr. and M. Guhathakurta, Erratum: Semiempirical Two-Dimensional Magnetohydrodynamic Model of the Solar Corona and Interplanetary Medium, *Astrophys. J.*, 564, 1062-1065, 2002.
- Sittler, E. C., Jr., L. Ofman, S. Gibson, M. Guhathakurta, J. Davila, R. Skoug, A. Fludra, and T. Holzer, Development of Multidimensional MHD Model for the Solar Corona and Solar Wind, *Solar Wind X*, ed. M. Velli, Pisa, Italy, in press, 2003.
- Sittler, E. C., Jr., R. E. Johnson, S. Jurac, J. Richardson, M. McGrath, F. Crary, D. Young, and J. E. Nordholt, Pickup Ions at Dione and Enceladus: Cassini Plasma Spectrometer Simulations, *J. Geophys. Res.*, in press, 2003.
- Sittler, E. C., Jr., R. E. Johnson, J. D. Richardson, S. Jurac, M. Moore, J. F. Cooper, B. H. Mauk, T. Armstrong, H. T. Smith, M. Michael, and B. Tsurutani, Energetic Nitrogen Ions Within the Inner Magnetosphere of Saturn, *J. Geophys. Res.*, in preparation, 2003.
- Sittler, E. C., Jr., Upcoming and Future Missions in the Area of Infrared Astronomy: Spacecraft and Ground-based Observations, *TDW'03 Conference at the University of Maryland*, ed. B. Lakew, in review, 2003.
- Slavin, J. A., D. H. Fairfield, R. P. Lepping, M. Hesse, A. Ieda, E. Tanskanen, N. Ostgaard, T. Mukai, T. Nagai, H. J. Singer, and P. R. Sutcliffe, Simultaneous Observations of Earthward Flow Bursts and Plasmoid Ejection During Magnetospheric Substorms, *J. Geophys. Res.*, 107(A7), 10.1029/2000JA003501, 2002.
- Slavin, J. A., R. P. Lepping, J. Gjerloev, D. H. Fairfield, M. Hesse, C. J. Owen, M. B. Moldwin, T. Nagai, A. Ieda, and T. Mukai, Geotail Observations of Magnetic Flux Ropes in the Plasma Sheet, *J. Geophys. Res.*, 108(A1), 1015, doi:10.1029/2002JA009557, 2003.
- Slavin, J. A., R. P. Lepping, J. Gjerloev, M. L. Goldstein, D. H. Fairfield, M. H. Acuña, A. Balogh, M. Dunlop, M. G. Kivelson, K. Khurana, A. Fazakerley, C. J. Owen, H. Réme, and J. M. Bosqued, Cluster Electric Field Current Density Measurements Within a Magnetic Flux Rope in the Plasma Sheet, *Geophys. Res. Lett.*, 30(7), 1362, doi:10.1029/2002GL016411, 2003.
- Slavin, J. A., C. J. Owen, M. W. Dunlop, E. Borälv, M. B. Moldwin, D. G. Sibeck, E. Tanskanen, M. L. Goldstein, A. Fazakerley, A. Balogh, E. Lucek, I. Richter, H. Reme and J. M. Bosqued, Cluster Four Spacecraft Measurements of Small Traveling Compression Regions in the Near-tail, submitted to *Geophys. Res. Lett.*, 2003.
- Smith, M. D., Interannual Variability in TES Atmospheric Observations of Mars During 1999-2003. *Icarus*, in press, 2003.

- Smith M. D., B. J. Conrath, J. C. Pearl, and P. R. Christensen, Thermal Emission Spectrometer Observations of Martian Planet-encircling Dust Storm 2001A, *Icarus*, 157 (1): 259-263 May 2002.
- Smith, M. D., The Annual Cycle of Water Vapor on Mars as Observed by the Thermal Emission Spectrometer, *J. Geophys. Res.*, in press, 2002.
- Smith, M. D., J. L. Bandfield, P. R. Christensen, and M. I. Richardson, THEMIS Infrared Observations of Atmospheric Dust and Water Ice Cloud Optical Depth, *J. Geophys. Res.*, in press, 2003.
- Steyert, D. W., W. F. Wang, J. M. Sirota, N. M. Donahue, and D. C. Reuter, Pressure Broadening Coefficients for Rotational Transitions of Water in the 380-600 cm^{-1} Range, *J.Q.S.R.T.*, 72, 775-782, 2002.
- Steyert, D. W., W. F. Wang, J. M. Sirota, N. M. Donahue, and D. C. Reuter, Hydrogen and Helium Pressure Broadening of Water Transitions in the 380-600 cm^{-1} Region, in press, *J.Q.S.R.T.*, 2002.
- Sugina, M., R. Fujii, S. Nozawa, T. Nagatsuma, S. C. Buchert, J. W. Gjerloev, and M. J. Kosch, Field-aligned Currents and Ionospheric Parameters Deduced from EISCAT Radar Measurements, *Ann. Geophys.*, accepted, 2002.
- Szabo, A., C. W. Smith, and R. M. Skoug, The Transition of Interplanetary Shocks Through the Magnetosheath, in *Proceedings of Solar Wind 10*, AIP Press, Pisa, Italy, in press, 2002.
- Taguchi, S, M. R. Collier, T. E. Moore, M. -C. Fok, and H. J. Singer, Response of Neutral Atom Emissions in the Low and High Latitude Magnetosheath Direction to the Magnetopause Shape and Motion, *J. Geophys. Res.*, in review, 2003.
- Tanskanen, E. H., E. J. Koskinen, T. I. Pulkkinen, J. A. Slavin, and K. Ogilvie, Dissipation to Joule Heating: Isolated and Stormtime Substorms, *Adv. Space Res.*, 30, 2305, 2002.
- Tanskanen, E. H., T. I. Pulkkinen, H. E. J. Koskinen, and J. A. Slavin, Substorm Energy Budget During Low and High Solar Activity: 1997 and 1999 Compared, *J. Geophys. Res.*, 107(A6), 10.1029/2000JA003501, 2002.
- Taylor, G. J., W. Boynton, D. Hamara, K. Kerry, D. Janes, J. Keller, W. Feldman, T. Prettyman, R. Reedy, J. Brückner, H. Wänke, L. Evans, R. Starr, S. Squyres, S. Karunatillake, and O. Gasnault, The Odyssey GRS Team, Igneous and Aqueous Processes on Mars: Evidence from Measurements of K and Th by the Mars Odyssey Gamma Ray Spectrometer, *Sixth International Conference on Mars*, July 20-25 2003, Pasadena, California, abstract no.3207, 2003.
- Taylor, G. J., W. Boynton, D. Hamara, K. Kerry, D. Janes, J. Keller, W. Feldman, T. Prettyman, R. Reedy, J. Brückner, H. Wänke, L. Evans, R. Starr, S. Squyres, S. Karunatillake, and O. Gasnault, Evolution of the Martian Crust: Evidence from Preliminary Potassium and Thorium Measurements by Mars Odyssey Gamma-Ray Spectrometer, *34th Annual Lunar and Planetary Science Conference*, March 17-21, League City, Texas, No. 2004, 2003.
- Temma, T., N. Chanover, A. Simon-Miller, D. Glenar, J. Hillman and D. Kuehn, Vertical Structure Modeling of Saturnian Equatorial Region from High Spectral Resolution Imaging. *Icarus*, submitted, 2003.
- Thejappa, G., R. J. MacDowall, E. E. Scime and J. E. Littleton, Evidence for electrostatic decay in the solar wind at 5.2 AU, *J. Geophys. Res.*, 108, A3, 1139, doi:10.1029/2002JA009290, 2003.
- Thejappa, G., P. Zlobec, and R. J. MacDowall, Polarization and Fragmentation of type II Radio Bursts, *Astrophys. J.*, 592, 1234, 2003.
- Thejappa, G. and R. J. MacDowall, Signatures of Langmuir Collapse in Type III Radio Burst Source Regions, *Nonlinear Processes in Geophysics*, submitted, 2003.
- Trivedi, N. B., D. G. Sibeck, E. Zesta, J. C. Santos, K. Yumoto, T. Kitamura, and S. L. G. Dutra, Signatures of Traveling Convection Vortices (TCV) in Ground Magnetograms Under the Equatorial Electrojet (EEJ), *J. Geophys. Res.*, 107, 10.1029/2001JA000153, 2002.
- Trombka, J. I., J. Schweitzer, C. Selavka, M. Dale, N. Gahn, S. Floyd, J. Marie, M. Hobson, J. Zeosky, K. Martin, T. McClannahan, P. Solomon, and E. Gottschang, Crime Scene Investigation Using Portable, Non-Destructive Space Exploration Technology, *Forensic Science International*, accepted for publication 2002.
- Tsurutani, B. T., X.-Y. Zhou, W. D. Gonzalez, R. P. Lepping, and V. Bothmer, Slow Magnetic Clouds, *JASTP*, accepted, 2003.
- Tsyganenko, N. A., A Model of the Near Magnetosphere with a Dawn-dusk Asymmetry 1. Mathematical Structure, *J. Geophys. Res.*, 107, 10.1029/2001JA000219, 2002.
- Tsyganenko, N. A., A Model of the Near Magnetosphere with a Dawn-dusk Asymmetry 2. Parameterization and Fitting to Observations, *J. Geophys. Res.*, 107, 10.1029/2001JA000220, 2002.
- Tsyganenko, N. A. and T. Mukai, Tail Plasma Sheet Models Derived from Geotail Particle Data, *J. Geophys. Res.*, v.108 (A3), 1136, doi: 10.1029/2002JA009707, 2003.
- Tsyganenko, N. A., H. J. Singer, and J. C. Kasper, Storm-time Distortion of the Inner Magnetosphere: How severe can it get? *J. Geophys. Res.*, v.108 (A5), 1209, doi: 10.1029/2002JA009808, 2003.
- Tsyganenko, N. A., and D. H. Fairfield, Global Shape of the Magnetotail Current Sheet Derived from Geotail and Polar Data, *J. Geophys. Res.*, submitted, June 2003.
- Trombka, J. I., two articles in *Unattended Radiation Sensor Systems for Remote Applications*, ed. J. I. Trombka, D. P. Spears and P. H. Solomon, published by American Institute of Physics, December 2002.

- Türk, F., Z. Kaymaz, and D. G. Sibeck, Search for a Magnetosheath Response to Foreshock Cavities, *Adv. Space Res.*, in press, 2002.
- Uritsky, V., A. J. Klimas, and D. Vassiliadis, Evaluation of Spreading Critical Exponents from the Spatiotemporal Evolution of Emission Regions in the Nighttime Aurora, *Geophys. Res. Lett.*, 30(15), art. no.-1813, 2003.
- Uritsky, V. M., A. J. Klimas, D. Vassiliadis, D. Chua, and G. D. Parks, Scale-free Statistics of Spatiotemporal Auroral Emissions as Depicted by POLAR UVI Images: The Dynamic Magnetosphere is an Avalanching System, *J. Geophys. Res.*, 107(A12), 1426, 2002.
- Usmanov, A. V., M. L. Goldstein, Three-dimensional MHD Modeling of the Solar Corona and Solar Wind, *Proceedings of Solar Wind 10*, in press, 2003.
- Usmanov, A. V. and M. L. Goldstein, A Tilted-dipole MHD Model of the Solar Corona and Solar Wind, *J. Geophys. Res.*, in press, 2003.
- Vaisberg, O. L., L. A. Avakov, T. E. Moore, and V. N. Smirnov, Ion Velocity Distributions Within LLBL and Their Possible Implication to Multiple Reconnection, *Ann. Geophys.*, in press, 2003.
- Valek, P. W., J. D. Perez, J.-M. Jahn, C. J. Pollock, M. P. Wuest, R. H. Friedel, T. E. Moore, and W. K. Peterson, Spatial Relationship Between Ionospheric Plasma Heating and Solar Wind Energy Input at the Cusp, *J. Geophys. Res.*, 107, in press, 2002.
- Valek, P. W., J. D. Perez, J.-M. Jahn, C. J. Pollock, M. P. Wuest, R. H. W. Friedel, T. E. Moore, and W. K. Peterson, Outflow from the Ionosphere in the Vicinity of the Cusp, *J. Geophys. Res.*, 107(A8), 10.1029/2001JA000107, 2002.
- Verigin, M., J. Slavin, A. Szabo, T. Gombosi, G. Kotova, O. Plochova, K. Szego, M. Tatralay, K. Kabin, and F. Shugaev, Planetary Bow Shocks: Gasdynamic Analytic Approach, *J. Geophys. Res.*, 108, doi:10.1029/2002JA009711, 2003.
- Verigin, M., J. Slavin, A. Szabo, G. Kotova, and T. Gombosi, Planetary Bow Shocks: Asymptotic MHD, *Earth Planets Space*, 54, 33, 2003.
- Verigin, M., D. Vignes, D. Crider, J. Slavin, M. Acuña, G. Kotova, A. Remizov, Martian Obstacle and Bow Shock: Origins of Boundary Anisotropy, *Adv. Space Sci.*, in press, 2003.
- Vignes, D., M. H. Acuña, J. E. P. Connerney, D. H. Crider, H. Rème, C. Mazelle, Factors Controlling the Location of the Bow Shock at Mars, *Geophys. Res. Lett.*, 29, 2002.
- Vondrak, R. and D. Crider, Ice at the Lunar Poles, *American Scientist*, 91, 322-329, 2003.
- Vondrak, R., J. Slavin, L. Zelenyi, L. Guhathakurta, S. Curtis, and B. Tsurutani, Measurement Strategies for Future Missions to Understand Geospace Dynamics, *AGU Monograph on Storm-Substorm relationships*, in press, 2003.
- Wasilewski, P. J., M. H. Acuña, and G. Kletetschka, 433 Eros, Problems with the Meteorite Magnetism Record in Attempting an Asteroid Match, *Meteoritics and Planetary Science*, 37, 937-950, 2002.
- Webb, P. A. and E. A. Essex, Modifications to the Titheridge Upper Ionosphere and Plasmasphere Temperature Model, *J. Geophys. Res.*, in press, 2003.
- Webb, P. A. and E. A. Essex, A Dynamic Global Model of the Plasmasphere, *J. Atmos. Solar-Terr. Phys.*, submitted, 2003.
- Weigel, R. S., D. Vassiliadis, and A. J. Klimas, Coupling of the Solar Wind to Temporal Fluctuations in Ground Magnetic Fields, *Geophys. Res. Lett.*, in press, 2002.
- Weimer, D. R., D. Ober, N. C. Maynard, W. J. Burke, M. R. Collier, D. J. McComas, N. F. Ness, and C. W. Smith, Variable Time Delays in the Propagation of the Interplanetary Magnetic Field, *J. Geophys. Res.*, 107(A8), SMP 29-1- SMP 29-15, 2001JA009102, 2002.
- Weimer, D. R., D. M. Ober, N. C. Maynard, M. R. Collier, D. J. McComas, N. F. Ness, C. W. Smith, and J. Watermann, Predicting Interplanetary Magnetic Field (IMF) Propagation Delay Times using Minimum Variance Technique, *J. Geophys. Res.*, 108(A1), SMP 16-1-16-12, 1026, 2002JA009405, 2003.
- Whang, Y. C., J. D. Richardson, L. F. Burlaga, and N. F. Ness, On Radial Heliospheric Magnetic Fields: Voyager 2 Observation and Model, *J. Geophys. Res.*, 108(A5), No.-1205, 2003.
- Whang, Y. C., L. F. Burlaga, Y. M. Wang, and N. R. Sheeley, Solar Wind Speed and Temperature Outside 10 AU and the Termination Shock, *Astrophys. J.*, 589(1), 635-643, 2003.
- Wilson, G. R., T. E. Moore, and M. Collier, Low Energy Neutral Atoms Observed near the Earth, *J. Geophys. Res.*, 108(A4), p. SMP 1-1-SMP 1-15, 2002JA009643, 2003.
- Wing, S., D.G. Sibeck, M. Wiltberger, and H. Singer, Geosynchronous Magnetic Field Temporal Response to the Solar Wind and IMF Variations, *J. Geophys. Res.*, 107, 10.1029/2001JA00915, 2002.
- Wong, M. H., G. L. Bjoraker, M. D. Smith, F. M. Flasar, and C. A. Nixon, Identification of the 10-micron Ammonia Ice Feature on Jupiter, *Planetary and Space Science*, in press, 2003.
- Wu, C.-C. and R. P. Lepping, The Effects of Magnetic Clouds on the Occurrences of Geomagnetic Storms: The First Four Years of Wind, *J. Geophys. Res.*, Paper no. 0148-0227/02, 2002.
- Wu, C.-C. and R. P. Lepping, Effect of Solar Wind Velocity on Magnetic Cloud-Associated Magnetic Storm Intensity, *J. Geophys. Res.*, 107, No. A11, doi:10.1029/2002JA00936, 2002.
- Wu, C.-C., K. Liou, R. P. Lepping, G. Le, and C.-I. Meng, Observations of Substorms during Prolonged Northward IMF Conditions, *Proceedings of the ICS-6*

Conference, ed. R. M. Winglee, Seattle, Washington, March 25-29, 376-381, 2002.

Wu, C.-C., R. P. Lepping, and N. Gopalswamy, Variations of Magnetic Clouds and CMEs with Solar Activity Cycle, *Proceedings of International Solar Cycle Studies Symposium 2003: Solar Variability as an Input to the Earth's Environment*, Tatranska Lomnica, Slovakia, June 23-28, in press, 2003a.

Wu, C.-C., K. Liou, R. P. Lepping, and C.-I. Meng, Identification of Substorms within Storms, *JASTP*, in press, 2003b.

Wu, S. T., A. H. Wang, and N. Gopalswamy, MHD Modeling of CME and CME Interactions in a Bi-modal Solar Wind: A Preliminary Analysis of the 20 January 2001 Two CMEs Interaction Event, in SOLMAG 2002, Proceedings of the Magnetic Coupling of the Solar Atmosphere Euroconference and IAU Colloquium 188, 11 - 15 June 2002, Santorini, Greece. Ed. H. Sawaya-Lacoste. ESA SP-505. Noordwijk, Netherlands: ESA Publications Division, p. 227, 2002.

Yang, Y.-H., J.-K. Chao, C.-H. Lin, J.-H. Shue, X.-Y. Wang, P. Song, C. T. Russell, R. P. Lepping, and A. J. Lazarus, Comparison of Three Magnetopause Prediction Models Under Extreme Solar Wind Conditions, *J. Geophys. Res.*, 107, SMP 3 - 1, 0.1029/2001JA000079, 2002.

Yashiro, S., N. Gopalswamy, G. Michalek, and R. A. Howard, Properties of Narrow Coronal Mass Ejections Observed with LASCO, *Adv. Space Res.*, in press, 2003.

Zhang, T. L., H. Zhao, G. Le, C. T. Russell, K. Schwimgenschuh, W. Riedler, G. C. Zhou, D. J. Wang, Z. X. Liu, Y. F. Gao, K. Y. Tang, and K. Yumoto, Polarization Characteristics of Dayside Pi 2 Pulsation on June 14, 1998, *Adv. Space Res.*, 30(10), 2339-2343, 2002.

Zheng, Y., M.-C. Fok, and G. V. Khazanov, A Radiation Belt - Ring Current Forecasting Model, *Space Weather*, in review, 2003.

Zhou, X.-Y., R. J. Strangeway, P. C. Anderson, D. G. Sibeck, B. T. Tsurutani, H. Haerendel, H. U. Frey, and J. K. Arballo, Shock Aurora: FAST and DMSP Observations, *J. Geophys. Res.*, 108, 10.1029/2002JA009701, 2003.